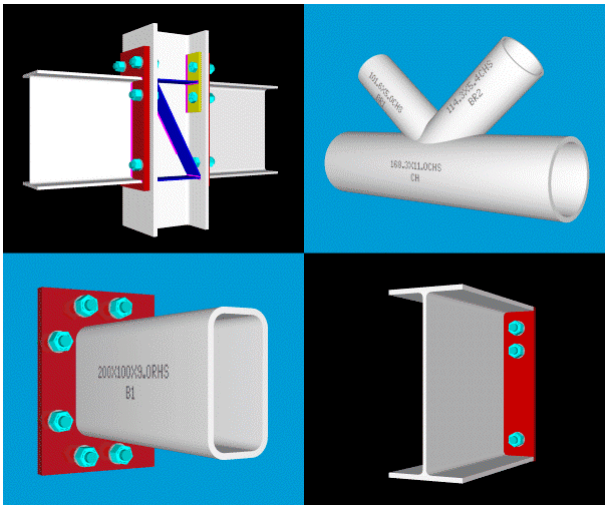
Limcon V3

User Manual

Engineering Systems



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Preface

Limcon first appeared in 1992 as a DOS program, companion to the Australian Steel Institute (ASI) publication *Design of Structural Connections – 4th Edition*. This was the principal reference for design of steel connections to the new limit states code for steel design, AS 4100-1990. Major enhancements were introduced in 2001 with Limcon V2. The conversion for Windows transformed the user interface and there were many additions, including virtual reality views of connections and integrated detailing with DXF output. Hollow section and other connections were added in Limcon V3 in 2003, together with support for the US, Canadian, and British codes.

Limcon V3.5 included support for the ANSI/AISC 360-05 design specification, which unifies the LRFD and ASD design methods. Although it has been integrated with the ProSteel CAD system (www.strucsoftsolutions.com) for some time, V3.5 is the first version of Limcon capable of integration with structural analysis programs, such as Microstran (www.microstran.com.au). This is possible by virtue of support for multiple load cases in many connections. Other additions in Limcon V3.5 were the implementation of the moment base plate according to the AISC publication, *Design Guide 1: Base Plate and Anchor Rod Design, Second Edition* and seismic design capability for some moment connections.

In 2008 the ASI began publishing its revised *Connections Series*, comprising design guides and design capacity tables. Limcon V3.55 incorporates the ASI 2008 models, many of which are closely related to AISC models detailed in the *Steel Construction Manual – 13th Edition* and AISC *Design Guides*. There are some additions to the ASI design models, including axial force in shear connections – see Chapter 4 for details. Support for Eurocode 3, BS EN 1993 : 2005 was added in 2009. Limcon does not implement the component method design models in EC3 but does apply EC3 rules to the existing AISC/ASI models.

Limcon V3.6 includes updates for ANSI/AISC 360-10 and CSA S16-09.

If the file Readme.txt is present in the Limcon folder after installation, you should read it for information that became available after this manual was printed. The file is automatically displayed during installation but it may be displayed in Notepad at any time by double-clicking the file in Windows Explorer.

The first version of Limcon fully compatible with this manual is V3.60.

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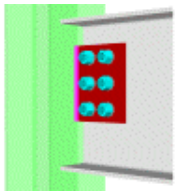
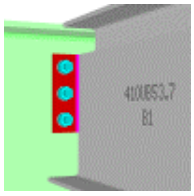
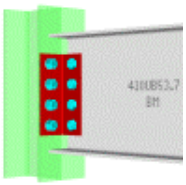
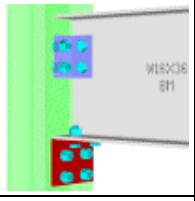
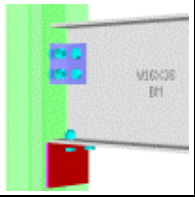
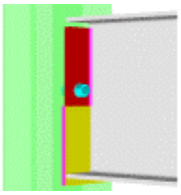
1:Introduction

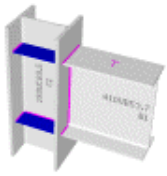
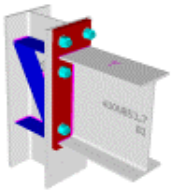
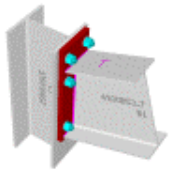
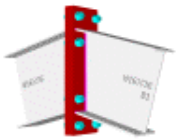
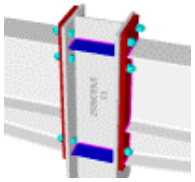
Connection Types

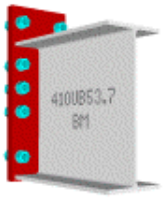
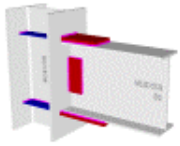
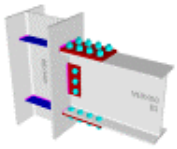
Simple (Shear) Connections

WSP		Web Side Plate Also known as fin plate, shear tab, or single plate connection. Extended plate available.
FEP		Flexible End Plate
ACLT		Angle Cleat
BAS		Bolted Angle Seat
WAS		Welded Angle Seat

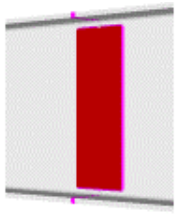
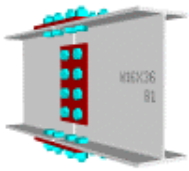
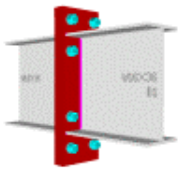
BPAD		Bearing Pad

Moment Connections

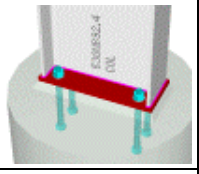
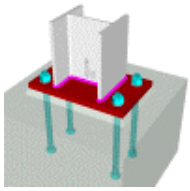
WBC		Welded Beam/Column Beam on one or both sides of column. With or without stiffeners or column web doubler plate.
BMEP A		Bolted Moment End Plate Beam on one or both sides of column. With or without stiffeners, column web doubler plates, and column flange doubler plates.
BMEP B		Bolted Moment End Plate Inclined beam on one or both sides of column. With or without stiffeners, column web doubler plates, and column flange doubler plates.
BMEP C		Bolted Moment End Plate Matching mitred end plates, apex connection in rigid frame, or end plate splice.
HBEP		Haunched Beam End Plate Rafter horizontal or inclined. Beam on one or both sides of column. With or without stiffeners, column web doubler plates, and column flange doubler plates.
MEPC F		Flush Moment End Plate One or two rows of bolts inside tension flange. Available for restricted range of I sections. May be used as splice.

MEPCE		Extended Moment End Plate One, two, or three rows of bolts inside tension flange – stiffeners available with one and three interior rows. May be used as splice. Seismic checking available for 4E and 4ES connections.
WFP		Welded Flange Plate Shear tab welded or bolted. Seismic checking available for fully welded connection.
BFP		Bolted Flange Plate Fully bolted. Seismic checking available.

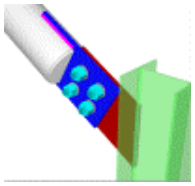
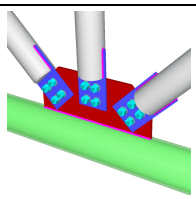
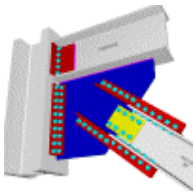
Splices

WSPL		Welded Splice Allocation of bending moment between flanges and web determined by analysis method, either elastic, plastic, or simplified.
BSPL		Bolted Splice Allocation of bending moment between flanges and web determined by analysis method, either simplified, elastic, or plastic.
BMEPS		Bolted End Plate Splice

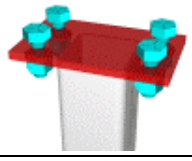
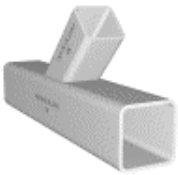
Base Plates

BASE		Base Plate Pinned connection. Member may be rolled or hollow section.
BASE M		Moment Base Plate Moment connection for I section column.

Bracing Connections

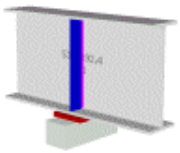
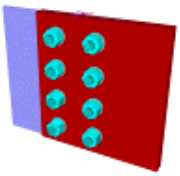
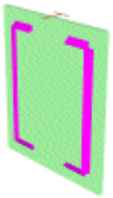
BRAC		Single Brace 20 types of bracing connection. Bracing member may be single or double angle, rod, flattened CHS, hollow section with cleat or tee plate, or rolled section.
KTG		KT Gusset Plate This is a compound bracing connection with two or three members connected to a gusset plate, which is welded to a beam, column, or truss chord. Each branch connection may be any one of the available single brace connection types. (Available only with maintenance.)
UFBR		Uniform Force Bracing Connection This is a compound bracing connection with one or two bracing members, each of which is connected to a gusset plate welded to a beam and bolted to a column. Each bracing connection may be any one of the available single brace connection types. (Available only with maintenance.)

Hollow Structural Section (HSS) Connections

TCAP		HSS Cap Plate Pinned connection. Design for tension.
KNEE		HSS Mitred Knee For RHS or SHS with width of both members the same. With or without stiffening plate.
TYT		HSS Y/T Chord may be RHS, SHS, CHS, or rolled section; brace may be RHS, SHS or CHS.
TX		HSS X Chord may be RHS, SHS, CHS, or rolled section; brace may be RHS, SHS or CHS.
TKNG		HSS K/N Gap Chord may be RHS, SHS, CHS, or rolled section; brace may be RHS, SHS or CHS.
TKNO		HSS K/N Overlap Chord may be RHS, SHS, CHS, or rolled section; brace may be RHS, SHS or CHS.
TMEP 4		4-Bolt RHS Bolted Moment End Plate For compact RHS or SHS only. This is a bending moment model – large axial forces are not permitted.

TMEP 8		8-Bolt RHS Bolted Moment End Plate For compact RHS or SHS only. This is a bending moment model – large axial forces are not permitted.

Miscellaneous Connections

SEAT		Stiff Seat End or internal support. With or without seat plate. With or without stiffeners.
BGP		Bolt Group Rectangular array of bolts in gusset of specified grade and thickness. May be analysed by either elastic or instantaneous center method.
WGP		Weld Group Many different configurations of fillet weld with in-plane and out of plane loading. Analysed by elastic method.

Design Code

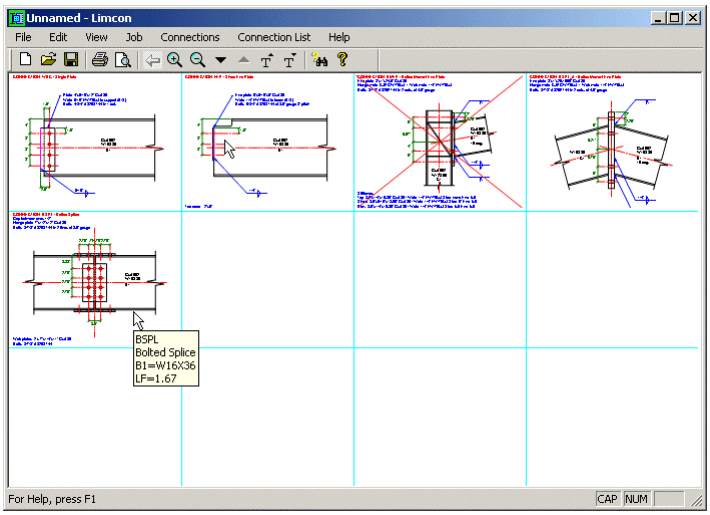
Limcon is supplied configured for one of the following design codes:

- ANSI/AISC 360 (Ref. 1)
- CAN/CSA-S16 (Ref. 2)
- BS 5950-1:2000 (Ref. 3)
- BS EN 1993-1-8:2005 (Ref. 47)
- AS 4100-1998 (Ref. 4)
- NZS 3404:Part 1:1997 (Ref. 5)

Each connection design model is essentially defined by the cited references but the relevant provisions of the configured design code take precedence where any difference occurs.

The **File > Configure > General** command permits the country and the section library to be changed. The country determines which steel grades may be used for plate components and the section library determines availability of steel sections and their grades.

The Limcon Window



THE LIMCON WINDOW

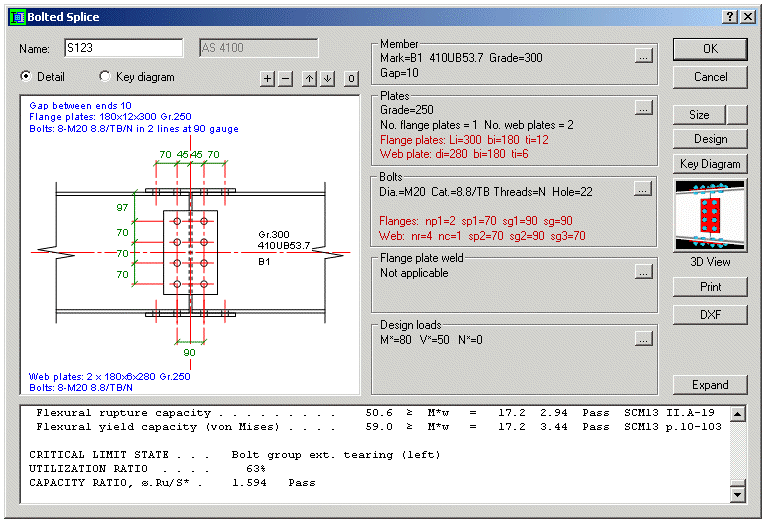
Right-clicking on a thumbnail displays a menu offering commands to show the connection at full size, edit, copy, delete, or print the connection.

The Limcon window is a multi-cell view with the main menu and toolbar at the top. Each connection in the current job is shown in miniature as a *thumbnail* in a cell. A *data tip* appears when the cursor passes over a cell containing a connection. Double-clicking on a thumbnail displays a dialog box with the connection data.

The main menu is the principal command interface. Each main menu item gives access to a drop-down menu of commands. In general, each toolbar button corresponds to a menu item. See Chapter 3 – “Menus & Toolbars” for a description of the drop-down menus.

You may right-click on a thumbnail to show a pop-up menu offering commands relevant to the thumbnail connection – see “Pop-Up Menu” on p. 37. The Notes commands allows you to enter notes for the connection that are added to the data tip (above).

Connection Dialog Boxes



DIALOG BOX FOR BOLTED SPLICE

Double-clicking on a thumbnail or selecting a command on the Connections menu displays a dialog box for the selected connection.

The connection name is shown in the box at the top left of the connection dialog box. This name, which must be unique within a job, is limited to 20 characters and must not contain space or tab characters or any of the characters shown below:

\ / " * ? :

While the **Detail** option button is selected, the window on the left shows the current configuration of the connection as a dimensioned detail diagram. Selecting the **Key diagram** option button replaces the detail diagram with a key diagram showing parameters and the sign convention for applied loads. The small buttons at the top of the detail diagram allow you to change the scale and positioning of the diagram within the cell.

The parameters defining the connection are shown in boxes on the right and an adjacent **Edit** or "**…**" button permits editing of any of the enclosed parameters. The **output window** at the bottom of the dialog box displays the results of the most recent check operation.

For some connection types there may be Size and Design buttons. The **Size** button sets plate dimensions to roughly match the section size, while the **Design** button initiates an automatic operation in which any item shown in red may change in order to make the capacity of the connection adequate for the applied loads. For some connections the Size button is split – the main part of the button completely changes the connection elements to fit the sections, while the small part of the button resizes connection elements without changing any bolt details.

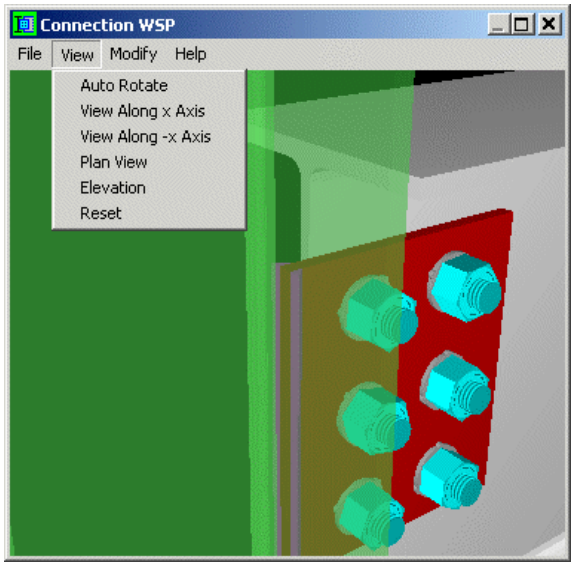
Clicking the **View** button displays a new window containing an OpenGL "virtual reality" view of the connection. The **Print** button prints a report containing a detail diagram and the current results, while the **DXF** button creates an AutoCAD format drawing exchange file containing a detail of the current connection.

The **Expand** button enlarges the output window, filling the entire dialog box, to show more of the results. Clicking the **X** button closes the expanded output window and returns to the dialog box.

The *check* operation, which is performed automatically, reports the capacity of the current connection configuration for all failure modes specified in the connection model. Where available, the *design* function uses an iterative method, automatically changing some connection parameters while seeking an optimum connection configuration for the design load. You may specify some connection parameters (e.g. bolt diameter) which are not changed during design. Parameters that may be modified by the design procedure cannot be specified and are displayed in red when design mode is selected.

Note: An exclamation mark shown on a connection detail indicates that the connection has failed at least one of the requirements of the design model. Check the connection output to see which condition has failed.

Virtual Reality (VR) Viewer



VIRTUAL REALITY VIEWER

Clicking the View button in a connection dialog box displays a new window containing an OpenGL *virtual reality* view of the connection. This view provides a useful visual check of arrangement and clearances. It is not available on displays with less than 16-bit color. Initially, the connection is shown rotating in the window. You may drag the mouse to rotate the view (left button depressed) or pan it (right button depressed). Keyboard arrow keys also rotate the view. Zoom by pressing the PageUp / Page Down keys or scrolling the mouse wheel. Double-click any point on the connection to make it the new center of rotation.

Colors Used

Different colors are used for different components. These are usually:

- Light grey – main members.
- Red – plates.
- Blue – stiffeners.
- Yellow – cover plates, flange doubler plates, shear keys.
- Green – web doubler plates.
- Magenta – welds.
- Cyan – nuts and bolts.
- Dark grey – washers.
- Translucent green – support members.
- Translucent blue – attached plates.

See “Configuration” on p. 17 for important information about the OpenGL pixel format.

The OpenGL window has these menus:

File Menu

The File menu offers commands to save a .JPG image and to print the image. Keyboard shortcuts for these commands are “J” and “P”, respectively.

View Menu

On the View menu you may select various fixed views, including a plan and elevation.

Modify Menu

The Modify menu offers commands to size (“S”) or design (“D”) the connection. These commands have the same effect as clicking the Size and Design buttons, if available, in the connection dialog box. There are also commands to locate the gusset plate on the other side of the member (“B”) and to reverse the bolts (“R”). Reversing the bolts is only for display purposes – the bolt direction is not a stored connection property.

Help Menu

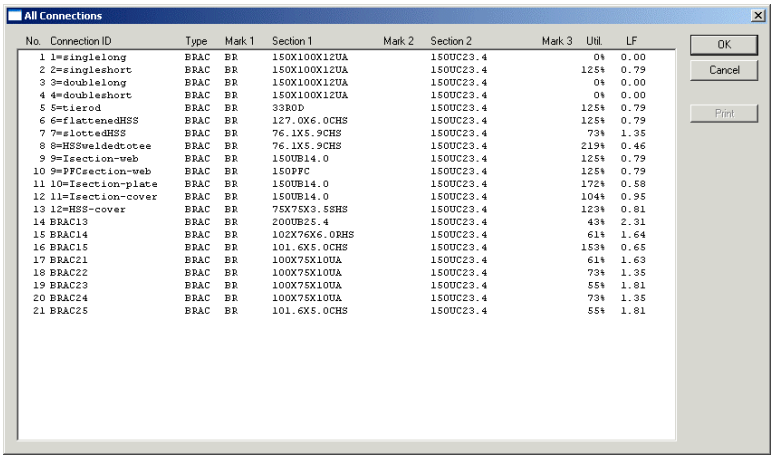
This menu gives help on colors used and keyboard and mouse commands and access to OpenGL information.

Listing All Connections in a Job

Select the **View > List > All** command to display all connections in the job in a tabular format. This command is also available on the pop-up menu that appears when you right-click on a connection thumbnail image. The right-most column shows the strength ratio or load factor for each connection. Values less than 1.0 indicate connections that are not satisfactory.

The **View > List > Passed** command shows only connections for which the strength ratio is 1.0 or greater while the **View > List > Failed** command displays only those for which the ratio is less than 1.0.

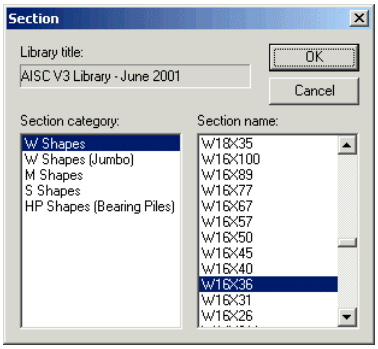
You may double-click on any line to display the corresponding connection dialog box.


All Connections
No. Connection ID Type Mark 1 Section 1 Mark 2 Section 2 Mark 3 Util. LF
1 1=singlelong BRAC BR 150X100X12UA 150UC23.4 0% 0.00
2 2=singleshort BRAC BR 150X100X12UA 150UC23.4 125% 0.79
3 3=doublelong BRAC BR 150X100X12UA 150UC23.4 0% 0.00
4 4=doubleshort BRAC BR 150X100X12UA 150UC23.4 0% 0.00
5 5=tierod BRAC BR 33ROD 150UC23.4 125% 0.79
6 6=flattenedHSS BRAC BR 127.0X6.0CHS 150UC23.4 125% 0.79
7 7=slottedHSS BRAC BR 76.1X5.9CHS 150UC23.4 73% 1.35
8 8=HSSweldedtotee BRAC BR 76.1X5.9CHS 150UC23.4 219% 0.46
9 9=Isection-web BRAC BR 150UB14.0 150UC23.4 125% 0.79
10 9=PFCsection-web BRAC BR 150PFC 150UC23.4 125% 0.79
11 10=Isection-plate BRAC BR 150UB14.0 150UC23.4 172% 0.58
12 11=Isection-cover BRAC BR 150UB14.0 150UC23.4 104% 0.95
13 12=HSS-cover BRAC BR 75X75X3.5SHS 150UC23.4 123% 0.81
14 BRAC13 BRAC BR 200UB25.4 150UC23.4 43% 2.31
15 BRAC14 BRAC BR 102X76X6.0RHS 150UC23.4 61% 1.64
16 BRAC15 BRAC BR 101.6X5.0CHS 150UC23.4 153% 0.65
17 BRAC21 BRAC BR 100X75X10UA 150UC23.4 61% 1.63
18 BRAC22 BRAC BR 100X75X10UA 150UC23.4 73% 1.35
19 BRAC23 BRAC BR 100X75X10UA 150UC23.4 55% 1.81
20 BRAC24 BRAC BR 100X75X10UA 150UC23.4 73% 1.35
21 BRAC25 BRAC BR 101.6X5.0CHS 150UC23.4 55% 1.81
OK
Cancel
Print

LIST ALL DIALOG BOX

Section Properties

Section properties are extracted from a library file containing standard steel sections. You can determine which library is used with the **File > Configure > Section Library** command.



CHOOSING A SECTION

A number of libraries are available for sections originating in countries including Australia, UK, US, Japan, and New Zealand. You may change any library or create a new one using Section Library Manager (see "Section Library Manager" on p. 94).

When you create a new connection default initial sections are used. The country configuration determines these default sections. For example, when configured for the US the default beam for the FEP connection is a W16X36. When configured for the UK it is a UB406X178X54 and when configured for Australia it is a 410UB53.7.

Steel Grades

Section Grades

The section library contains information about steel grades available for each section. When you choose a section you must also choose a steel grade from those available. If the grade required is not shown in the grade list box you can easily add it by editing the section library.

Plate Component Grades

Plates are available in certain grades depending on the country setting. For example, the usual plate grade in the US is A36, it is S275 in the UK, and in Australia it is 250 (AS/NZS 3678). For more detailed information on grades of plate components, see "Steel Grades" on p. 39.

Computer Requirements

Recommended

- Windows XP or later.
- 1024 x 768 resolution or higher.
- 32-bit color.
- Color printer.

Virtual Reality Graphics

The View button in Limcon connection dialog boxes displays an OpenGL virtual reality representation of the connection. Virtual reality is only available on displays with 65535 or more colors. To see the color capability of your display, go to the Settings page of Display Properties in the Windows Control Panel. The necessary minimum color depth is High Color (16 bit). Display adapter memory and screen resolution are the main factors affecting the color depth available. If your display has the necessary color depth and virtual reality graphics is still not available, you may need to set the OpenGL pixel format – see "Configuration" on p. 17.

2:Getting Started

Installing Limcon

The Setup program will install Limcon on your computer. You must have Administrator privileges to install Limcon.

Place the Limcon CD-ROM into your drive and the installation will start automatically. Setup will guide you through the installation process, prompting you as required.

A number of folders will be established under the specified Limcon folder. If you use the default name the folders as displayed in Windows Explorer will look like this:

Folder Name	Comment
Limcon	Limcon folder – you can choose this name during installation. The default is Limcon.
.....Data	Default data folder – you can open Limcon files in other folders if you wish.
.....Lib	Library files, design parameter files, and template files.
.....PDF	Adobe Acrobat PDFs.
.....Program	All Limcon program files and Help files.

Hardware Lock

Limcon is normally supplied with a hardware lock that must be attached to a USB port before you can start the program. Any drivers required for the hardware lock will be installed automatically when you install Limcon. Additional set-up procedures are required for systems with a network lock. These are described on data sheet supplied with the software.

Starting Limcon

The Setup program creates a Limcon icon on the Windows All Programs menu. Select **Start > All Programs > Limcon** to start Limcon.

Note the following help features, which make it easier for you to use Limcon:

- There are **tooltips** on all toolbar buttons. Move the mouse cursor over the button for a moment and a little pop-up window displays the function of the button.
- There is a prompt displayed on the left side of the status bar (at the bottom of the Limcon window) whenever the cursor is positioned over a toolbar button or a menu item.
- Context-sensitive (pop-up) help is available in most dialog boxes. Some items in dialog boxes also have tooltips.

Use the **Help > Limcon Help Topics** command to display the Help Topics dialog box. With this, you can browse the table of contents, look through an index, or search all help topic keywords.

Font

Limcon requires the font MS LineDraw. During installation this font is installed automatically using the file Linedraw.ttf on the distribution CD. When setting up Limcon on a workstation without installing from the CD you must ensure that MS LineDraw is installed.

If unusual characters are seen in Print Preview it could mean that MS LineDraw is not properly installed or the system has not been rebooted after installation of the font.

How to Make a Shortcut on the Desktop

To make a shortcut to Limcon on your *desktop* (the background that is visible when no programs are running), right-click on the desktop, select **New > Shortcut**, and in the Create Shortcut dialog box browse to the Lmc3.exe file in the Limcon \Program folder. Set the "Start in" folder to the data folder. Enter **Limcon** for the name of the shortcut, and click the **Finish** button. Alternatively, drag the Limcon icon from the Start menu to the desktop with the mouse while pressing the Ctrl key.

Launch with Double-Click

Limcon job files (Job.lmc, where "Job" is the job name) should be identified in Explorer with the Limcon icon. It is convenient to be able to double-click on one of these files in Explorer to start Limcon with the job. To do this, the LMC file type must be associated with Limcon.

The association between Limcon and the LMC file type may be established when Limcon is installed. You may also establish the association with the procedure set out below.

These are the steps necessary to make Limcon launch with a double-click:

- In Explorer select the **View > Folder Options** or **View > Options** command.
- Select the File Types tab.
- In the list box search for the Limcon job file type, which may be shown as "LMC File" or "Limcon Job File". If found, select this file type and click the Remove button. Close the dialog box.
- In Explorer browse to the Limcon data folder and double-click on any Limcon job file (if the file name extension "lmc" is not visible you may see it by right-clicking and displaying the properties of the file).
- The Open With dialog box appears. Click on the Other button and browse to the Limcon \Program folder and select Lmc3.exe.
- In the Description box type "Limcon Job File" and click OK.

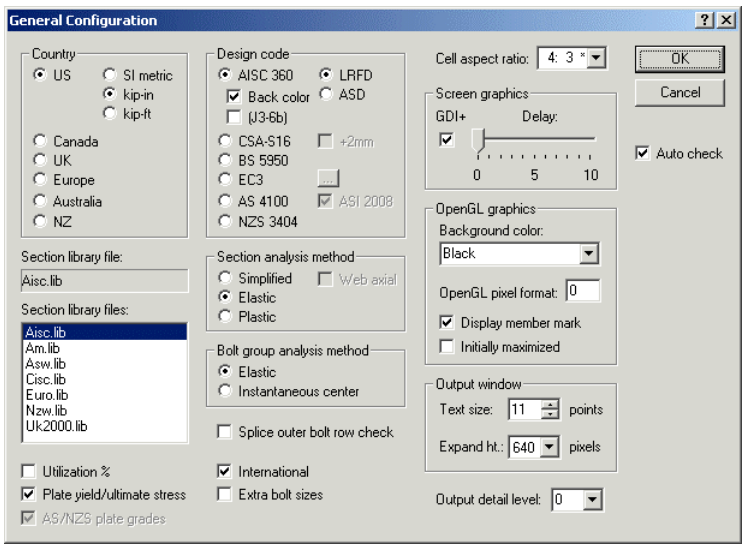
Now, check that you have successfully set up your system by browsing to a Limcon job file and double-clicking.

Configuration

The **File > Configure** command allows you to set the default library file, edit library files, set text size, and set OpenGL parameters. Configuration settings are saved from run to run, for each user.

Configuration settings are saved in the Windows registry under the HKEY_CURRENT_USER key. When you start a new job configuration settings remain as they were at the last run. You may reset configuration settings to their default values by running the LmcReset.exe in the Limcon \Program folder.

The **File** > **Configure** > **General** command displays the dialog box below. In this you may change settings that affect the way Limcon works.



GENERAL CONFIGURATION

Configuration items are:

Country

This determines plate grades, bolt diameters, bolt categories, and weld grades available. SI metric units are used unless the country setting is US and either the “kip-in” or “kip-ft” box is checked.

Design code

Rules for checking a connection are determined by this setting. When Limcon is supplied it is validated for design to one or more design codes. Only validated design codes are enabled. The connection design model may vary with the selected design code.

When AISC 360 is selected either LRFD or ASD may also be selected. With the “Back color” box checked the background of the connection view is lightly colored blue or green, respectively, for LRFD and ASD.

When CSA-S16 is selected the “+2mm” box may be checked to allow an additional 2mm for the diameter of bolt holes, as required by Cl. 12.3.2 when holes are not drilled.

With EC3 selected the associated button permits the input of gamma values, which may depend on the EC3 national annex in effect. Default values are those specified in the UK national annexes.

Section library file

The currently selected section library file.

Section library files

A list of all available section library files. See “Folders” for the location of the library folder.

Section analysis method

The method used for determining the distribution of forces between flanges and web in moment connections and splices. See “Rigid Connections” on p. 54.

Splice outer bolt row check

When the shear force in a bolted splice is large there may be a significant increase in bending moment from the center of the splice to the outer bolt row, where flange and plate net section checks are performed. Checking this box lets you take this into account automatically. See “Bolted Splice (BSPL)” on p. 56.

Bolt group analysis method

The method used for determining the in-plane strength of an eccentrically loaded bolt group. See “Bolt Group (BGP)” on p. 79.

Utilization %

With this item checked the report gives the percentage utilization (or demand/capacity ratio) for each limit state checked. Otherwise, the report shows a strength ratio, the reciprocal of the utilization ratio.

Plate yield/ultimate stress

With this item checked you will be able to specify yield and ultimate stresses for the plate material. This will be required when the necessary plate grade is not available in a pull-down list.

AS/NZS plate grades

Checking this item makes available plate grades additional to the normal Australian 250 and 300+ grades.

International

Checking this item allows you to choose any known international grade for sections and plates. Section grades can otherwise be chosen only from the grades nominated for each section in the library. This setting also allows you to choose any international bolting category.

Extra bolts

By checking this item you may include M22 and M27 bolts, which are not preferred sizes, and bolts larger than M36 in bolt size pull-down lists. Bolts larger than M36 may be required for base plates.

Auto check

With this box checked Limcon automatically attempts to check from the internet whether the main executable file is the latest available. This check occurs only on the first run for any day. With this box checked

Limcon may also attempt to check from the internet whether maintenance is current.

Output detail level

To facilitate checking of results Limcon can show additional output, which includes input parameters and intermediate results. You may select a level from 1 to 3 to determine how much additional output is shown for each connection. Level 0 indicates a normal output without any additional detail.

Cell aspect ratio

Limcon's main view is sub-divided into multiple cells, each of which may contain a connection thumbnail image. You may change the aspect ratio of the cells using this item. The default value is 4:3 (landscape). Other values between 1:2 and 2:1 are available in the combo box.

Screen graphics

Windows screen graphics is based on GDI, the *Graphics Device Interface*. GDI+, released in Windows XP, is an optional enhancement that provides higher quality screen graphics than previously attainable.

GDI+

Check this box to use GDI+. This option may not work properly on older computers. The Delay control may be set if you experience problems with GDI+.

Delay

This control is only required if screen graphics does not work properly with GDI+. If screen images are incomplete select the minimum value that fixes the problem.

OpenGL graphics

OpenGL is the graphics system used in Windows for display of virtual reality (VR) images.

Background color

Background color may be black, sky blue, or white.

OpenGL pixel format

On computers supporting OpenGL there are 24 or more *pixel formats*, only some of which are suitable for Limcon's virtual reality viewer. When the pixel format in the OpenGL Configuration dialog box is set to zero a suitable pixel format is chosen automatically. If your display has the necessary color depth and the virtual reality viewer does not work, you may need to set the pixel format. Contact Limcon support if you need help choosing an appropriate pixel format.

WARNING: Use of an inappropriate value may crash your system.

Display member mark

With this item checked Limcon virtual reality views show the mark and name of steel sections.

Initially maximized

With this item checked the OpenGL VR window fills the whole screen.

Output window

The text size for the output window in connection dialog boxes – normal size is 11 or 12. This does not affect the size of printed text, which is determined in Page Setup – see "The Page Setup Dialog Box" on p. 23.

Expand ht.

The initial height of the output window may be increased by selecting a non-zero value in this box.

Limcon Commands

Limcon commands are available from:

- The main menu.
- Toolbar buttons.
- The context menu.

All program commands are available on the main menu and commonly used commands are also available on toolbar buttons or the context menu for added convenience. Commands selected from the main menu are referred to as shown in this example:

File > Print Preview

Commands selected by clicking a toolbar button are referred to by the name of the button, as shown in the tooltip.

Units

Limcon can be configured to use SI metric units or US customary units (see "Configuration" on p. 17). The units used are:

Item	SI Metric	US Customary
Dimension	mm	in.
Force	kN	kip
Moment	kN.m	kip-in *or* kip-ft
Stress	MPa (N/mm2)	ksi
Force per unit length	kN/mm	kip/in
Angle	degree	degree
Rotation	radian	radian

When the country setting is US the lists of available bolt sizes and plate thicknesses will include US customary sizes, regardless of the units setting. Metric bolt sizes and plate thicknesses are only available for the US country setting when US customary units are *not* used.

The units used in section libraries are those customarily used in the country of origin. When using Section Library Manager to modify a library or make a new one, the library units are used.

Modifying the Steel Section Library

A source file is supplied with each steel section library. The source file is a text file with the file name extension "asc" and the corresponding library file has a file name extension of "lib" (e.g. Uk2000.asc, Uk2000.lib). Use the **File** > **Configure** > **Section Library Manager** command to modify a library. *It is recommended that you do not modify the standard library supplied with Limcon – it is preferable to copy the library to a new one with a different name and then modify that.*

See Chapter 6 for more information on Section Library Manager.

Printing in Limcon

Print and Print Preview Commands

Limcon has a Print command on the File menu (**File > Print**). This is for printing connection details – either multiple connections, or just one connection at a large scale.

The **File > Print Preview** command is for previewing the picture that would be printed by the **File > Print** command. The preview shows exactly what the printed page will look like* so you can check margins and page orientation without wasting paper.

* If the preview shows a logo but it is not printed, there may be a problem with the printer driver.

Printing Reports and VR Images

In addition to the Print command on the File menu there is also a Print button on each connection dialog box that is used for printing a report, including a diagram, for the current connection.

Each connection dialog box has a 3D View button, which displays a virtual reality image of the connection. This image may be printed using the Print Image command on the File menu at the top of the VR image.

Print previews are not available for connection reports or VR images.

The Page Setup Dialog Box

The Page Setup dialog box allows you to change settings affecting the layout of graphical output or reports.

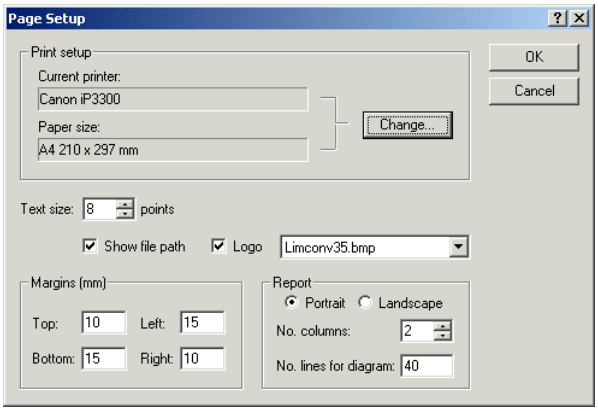
The current printer, shown in the Page Setup dialog box, is initially the Windows default printer and remains so until a different printer is selected. A new current printer may be selected in the Windows Print Setup dialog box that is shown when you click the Change button. You may also change the current printer in the Windows Print dialog box, shown when you select the **File > Print** command from the main menu.

Text Size

The text size, in points, for reports. There are 72 points to the inch. The default value is 8.

Logo

Check this box if you want Limcon to print a logo at the top of each page of printed output. When the box is checked you may choose one of the available bitmap files from the adjacent combo box. See “Configurable User Graphic on Reports” on p. 24.



PAGE SETUP

Report

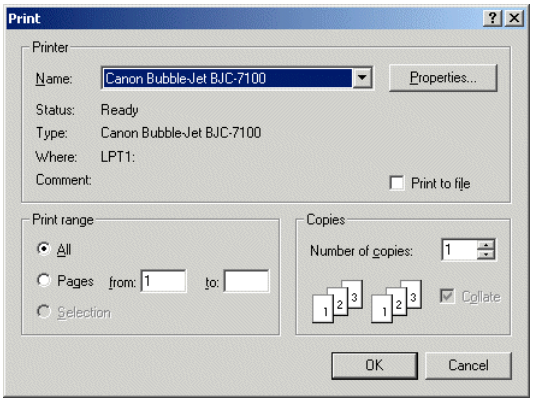
Limcon reports may be printed in portrait or landscape orientation. Multi-column reports are available as long as there is room on the page. When there is insufficient room for the number of columns selected the number of columns is automatically reduced as required. To increase the density of printing in a report you may increase the number of columns and reduce the text size and margins.

The Windows Print Dialog Box

The **File > Print** command displays the Windows Print dialog box so you can change the target printer, the number of copies, or printer settings with the Properties button. When you click OK in this dialog

box the selected printer becomes the current printer. Clicking the Print button on the main toolbar initiates a graphics print *without* the display of the Windows Print dialog box. The view is printed immediately to the current printer – notice that the tooltip for the Print button shows the name of the current printer.

The Print button in each connection dialog box also displays the Windows Print dialog box before printing.



WINDOWS PRINT DIALOG BOX

Note: Clicking the Properties button displays the printer properties dialog box. The page orientation setting in this dialog box is ignored as Limcon uses the orientation setting from the Page Setup dialog box for reports and landscape for graphics.

The Preview command, **File > Print Preview**, and the Preview button do not display the Windows Print dialog box. The preview is always for the current printer. When you see a print preview on the screen there is a Print button at the top left of the preview window. Clicking this will initiate printing on the current printer. If you want to change the current printer after seeing a preview, close the preview window and then select the **File > Print** command.

Configurable User Graphic on Reports

You may use this feature to place your company logo at the top of all printed output.

Limcon allows you to have a small graphic at the top of each page of printed output. Any valid Windows bitmap file existing in the \Program folder may be selected in the Page Setup dialog box. Select the logo option to print the graphic on each page. If the option is not selected no graphic will be printed and no space will be allowed for it. On installation Limcon is configured to use the graphic shown below. You can unselect the option in Page Setup if you do not want a graphic.

Limcon V3.6

DEFAULT GRAPHIC

The specification of the bitmap is:

- Width – 1200 pixels
- Height – 200 pixels
- Colors – 256

Limcon prints the graphic in a space 50.8 mm wide and 8.5 mm high.

Note: The Windows drivers for some printers do not support the printing of bitmaps. In such cases the logo may be shown in the print preview without actually printing.

Help Features

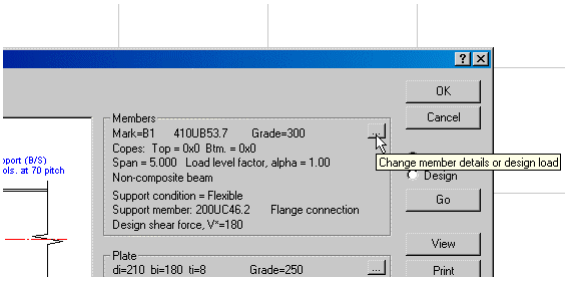
Note the following help features, which make it easier for you to use Limcon:

Command Help

There is a prompt displayed on the left side of the status bar (at the bottom of the Limcon window) whenever the cursor is positioned over a toolbar button or a menu item.

Tooltips in Dialog Boxes

Dialog boxes have tooltips, which appear when the mouse cursor passes over some dialog box controls.

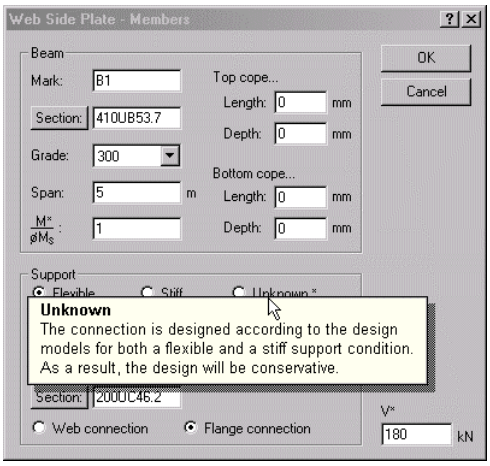


Context-Sensitive (Pop-Up) Help

Context-sensitive Help gives quick access to information about dialog box items simply by clicking the question-mark button in the title bar and then clicking the item. Many dialog boxes in Limcon have context-sensitive help, a typical example of which is shown below.

The Windows component necessary for pop-up help, WinHlp32.exe, is not included in Windows Vista and Windows 7. It may be downloaded from the Microsoft website, see:
http://support.microsoft.com/kb/917607

Policy defaults on a domain based network may block the use of .hlp files over a network. The administrator can modify domain policy to permit this if required.



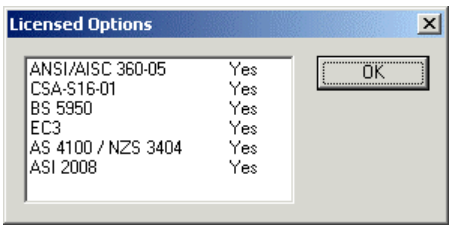
On-Line (HTML) Help

Limcon's on-line help allows you to browse help topics, look through an index, or do a full-text search for any word or phrase. The entire Limcon User Manual is available through on-line help.

Windows security prevents HTML help files (.chm files) being accessible over a network. This means that if the Limcon \Program folder is on the network rather than a local disk HTML help will only be available if the Limcon3.chm file is on a local disk.

Licensed Options

Limcon is usually supplied for only one design code and capability for more design codes is available at additional charge. Click the Licensed Options button in the Help About Limcon dialog box to display the design codes that may be selected. Codes for which "Yes" is displayed may be selected in the General Configuration dialog box.



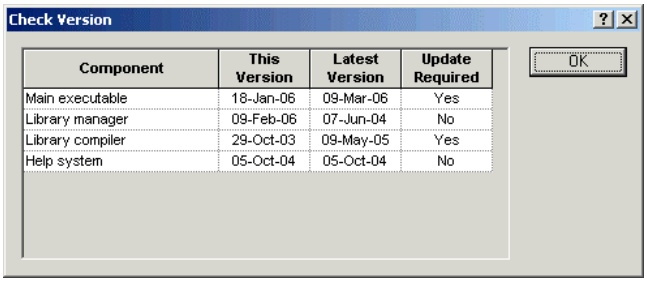
NOTE: The ASI 2008 option is relevant for AS 4100 and NZS 3404 only. When either of these is the configured code, available new ASI models will be used only if the ASI 2008 option is "Yes".

Data from Earlier Versions

Limcon V3 reads data files created by Limcon V2.

Web Update

You may use the web update facility in Limcon to determine when an update is required. While your computer is connected to the internet, clicking the Check Version button in the Help About dialog box displays the dialog box shown below. This displays the dates of your Limcon software and dates of the current web downloads so you can see whether an update is required.



You can connect to the Limcon website by clicking the Downloads hot link in the Help About dialog box. Here, you will find the components you need to download. Each is an executable file – run it to unpack the update files. Please submit the form on the web page to obtain the necessary passwords.

A new CD may be purchased as an alternative to using the internet download facility.

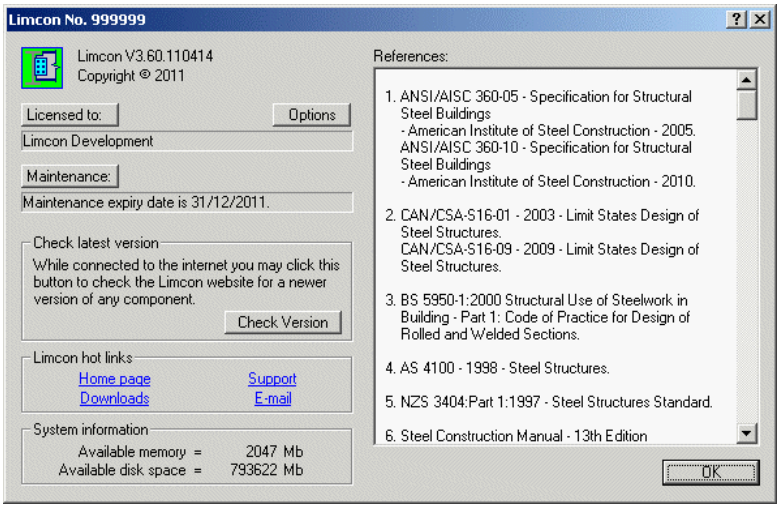
New versions or major *upgrades* may not be downloaded from the Limcon website but may be purchased on CD when available.

Maintenance & Technical Support

Technical support is available to licensed users with maintenance. When Limcon is supplied maintenance is included for an initial period, which may vary from 6 to 12 months depending on local arrangements. Maintenance may be renewed when the maintenance period expires. *Apart from ensuring the availability of technical support, current maintenance also allows continued availability of some advanced features, including the UFBR connection, and recent developments.*

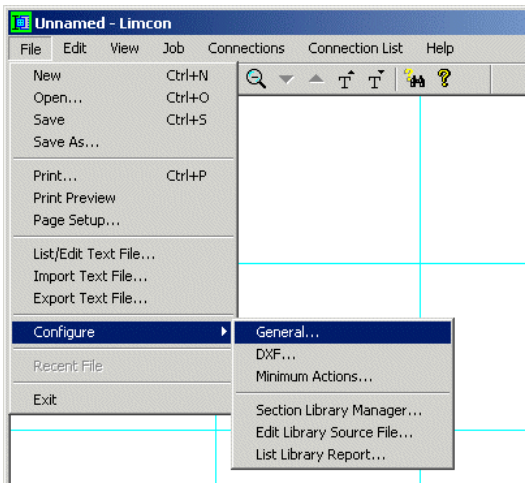
Use the **Help > About Limcon** command to display the serial number, the exact version number and configuration of your software, and the maintenance expiry date. This information is required when you ask for technical support. In addition, the Help About dialog box contains hot-links directly to the Limcon website on the internet and to e-mail Support.

NOTE: With "Auto check" enabled in general configuration Limcon can obtain up to date information about your maintenance status.


Limcon No. 999999
Limcon V3.60.110414
Copyright © 2011
Licensed to:
Options
Limcon Development
Maintenance:
Maintenance expiry date is 31/12/2011.
Check latest version
While connected to the internet you may click this button to check the Limcon website for a newer version of any component.
Check Version
Limcon hot links
Home page
Support
Downloads
E-mail
System information
Available memory = 2047 Mb
Available disk space = 793622 Mb
References:
1. ANSI/AISC 360-05 - Specification for Structural Steel Buildings - American Institute of Steel Construction - 2005. ANSI/AISC 360-10 - Specification for Structural Steel Buildings - American Institute of Steel Construction - 2010.
2. CAN/CSA-S16-01 - 2003 - Limit States Design of Steel Structures. CAN/CSA-S16-09 - 2009 - Limit States Design of Steel Structures.
3. BS 5950-1:2000 Structural Use of Steelwork in Building - Part 1: Code of Practice for Design of Rolled and Welded Sections.
4. AS 4100 - 1998 - Steel Structures.
5. NZS 3404:Part 1:1997 - Steel Structures Standard.
6. Steel Construction Manual - 13th Edition
OK

3:Menus & Toolbars

File Menu

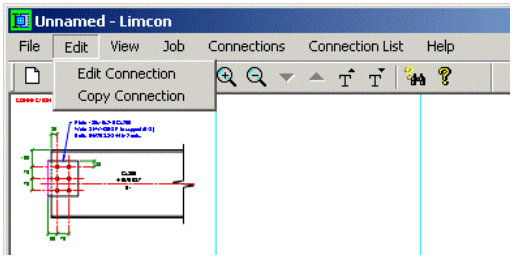


The File menu offers the following commands:

Command	Action
New	Create a new job.
Open	Open an existing job.
Save	Save the current job using the same file name.
Save As	Save the current job to a specified file name and changes the name of the current job accordingly.
Print	Print the current view.
Print Preview	Display the view as it would appear printed.
Page Setup	Change the printing options.
List/Edit Text File	Opens the selected text file with the MsEdit text editor for viewing or editing.
Import Text File	Reads data into Limcon from a suitable text file.
Export Text File	Writes Limcon data to a text file for input to another program.

Configure	Configuration settings, Section Library Manager.
Recent File	Select recently used job.
Exit	Exit Limcon

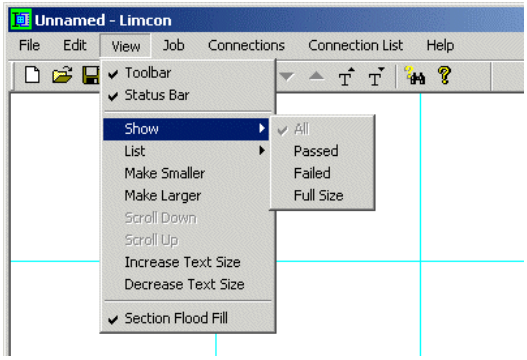
Edit Menu



The Edit menu offers the following commands:

Command	Action
Edit Connection	Edit a connection. Click on a connection to select it for editing.
Copy Connection	Copy a connection. Click on a connection to select it for copying to a new connection. The new connection name is derived from that of the source connection.

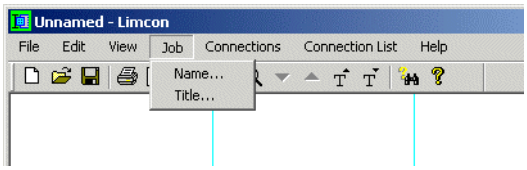
View Menu



The View menu offers the following commands:

Command	Action
Toolbar	Shows the toolbar.
Status Bar	Shows the status bar.
Show > All	Shows all connections in the current job, up to the number of cells in the view. You may increase the number of cells displayed with the **View > Make Smaller** command.
Show > Passed	Shows only connections whose strength ratio is 1.0 or greater.
Show > Failed	Shows only connections whose strength ratio is less than 1.0.
Show > Full Size	Permits selection of a connection to be shown filling the view. Use the **Show > All** command, the Back button, or **Esc** to restore the view to its previous state.
List > All	Lists all connections in the current job in a table. Connections are listed alphabetically by name with connection type, member mark and section, and strength ratio.
List > Passed	Lists only connections whose strength ratio is 1.0 or greater.
List > Failed	Lists only connections whose strength ratio is less than 1.0.
Make Smaller	Redraws the current view with an additional column. This reduces the scale at which connection thumbnails are shown. The number of rows is determined automatically according to the size of the main window.
Make Larger	Redraws the current view with one less column. This enlarges the scale at which connection thumbnails are shown.
Scroll Down	Redraws the current view moving each row of connections up one cell (the top row disappears).
Scroll Up	Redraws the current view moving each row of connections down one cell (the bottom row may disappear).
Increase Text Size	Increases size of text in all connection diagrams – may cause overplotting.
Decrease Text Size	Reduces size of text in all connection diagrams – reduces overplotting in complex diagrams.
Section Flood Fill	Where a cross-section is shown, draws the steel shape filled with yellow.

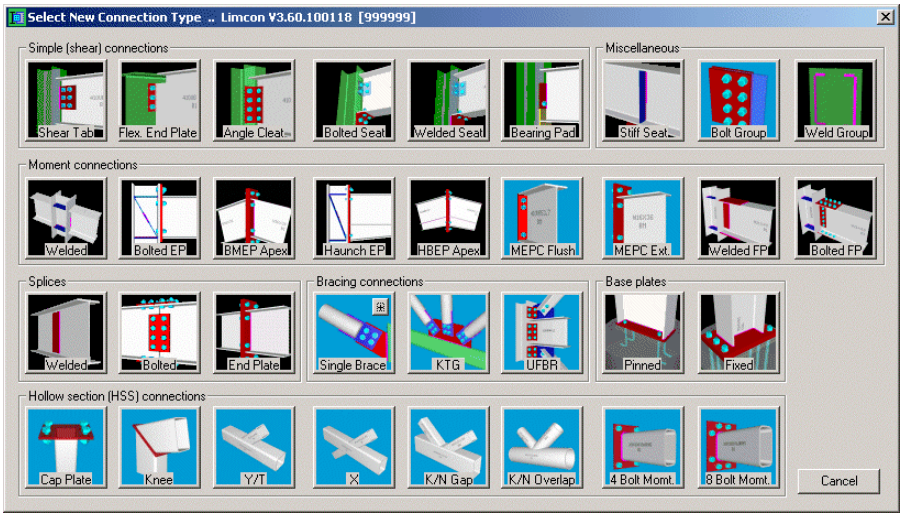
Job Menu



The Job menu allows input of the job description.

Command	Action
Name	Allows input of the job name. When Limcon starts from a shortcut the initial job name is “Unnamed”. Select this command to change the job name.
Title	Allows input of the job description shown on printed output.

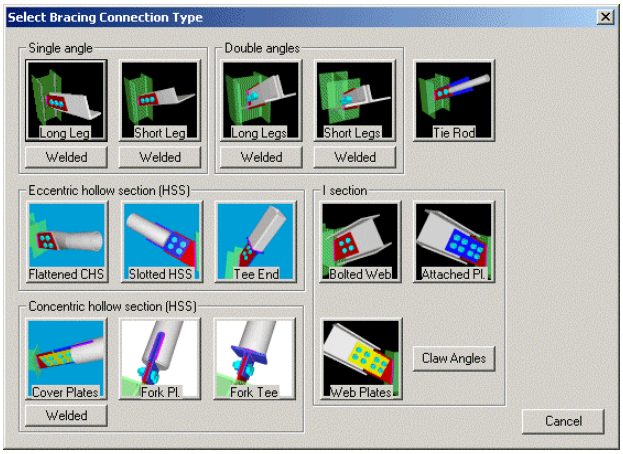
Connections Menu



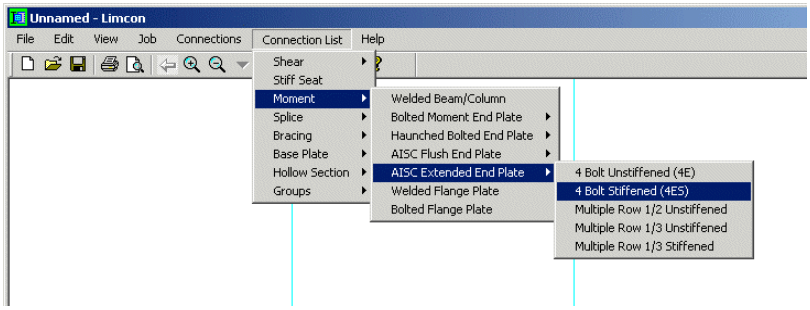
This menu is in the form of a window with an image button for each connection type. Some connections are available in certain sub-types that may be selected in the connection dialog box. For example, the Angle Cleat button selects an angle cleat connection that is bolted to the beam and the support but you may change this to a welded type in the next dialog box to appear.

The Simple Brace button selects a slotted HSS bracing connection but clicking the small button at the top right of this button displays another

dialog box, shown below, that contains image buttons for each of the available types of simple bracing connection.

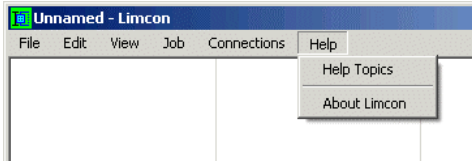


Connections List Menu



The Connections List menu is a hierarchical menu of all available connection types. The top menu level allows you to choose a general connection type while the second and third levels offer further sub-division of connection type.

Help Menu



The Help menu offers the following commands:

Command	Action
Help Topics	Display the Help Topics dialog box. This has three tabs, Contents, Index, and Search, so you can easily find help topics.
About Limcon	Display details about this copy of Limcon and system resources. Also contains links to the internet.

Main Toolbar

The Main toolbar offers the following commands:

Open a new job.

Open an existing job. Limcon displays the Open dialog box, in which you can locate and open the desired file. This command is for opening an existing job (one previously saved from Limcon).

Save the job.

Print the view; i.e. print a picture showing all thumbnail cells currently displayed. Use the **Print** button in each connection dialog box to print a report.

Print preview; i.e. display exactly how the graphics will be printed.

Back. Click this button to go back to the view of all connections after showing a connection at full size. Pressing **Esc** has the same effect.

Remove column. Connections will be shown at a larger scale.

Add column. Connections will be shown at a smaller scale to accommodate an extra column.

Scroll down one row.

Scroll up one row.

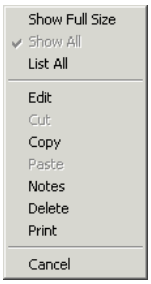
Make text larger. Increases size of text in all connection diagrams – may cause overplotting.

Make text smaller. Reduces size of text in all connection diagrams – reduces overplotting in complex diagrams.

Help Topics – on-line Help contains all information in the manual.

Help About Limcon.

Pop-Up Menu



The pop-up menu appears when you right-click a connection thumbnail. It offers these commands:

Command	Action
Show Full Size	Fills the main view with the right-clicked connection.
Show All	Reverts to view of multiple connection thumbnails after selection of Show Full Size command.
List All	Shows a list of all connections in the job. See “Listing All Connections in a Job” on p. 12.
Edit	Displays the right-clicked connection in a dialog box for editing. Double-clicking the connection has the same effect.
Cut	Removes the right-clicked connection from the view and places it on the clipboard for pasting.
Paste	Inserts the clipboard connection before the right-clicked connection.
Notes	Displays a dialog box for entering notes for the right-clicked connection.
Delete	Deletes the right-clicked connection.
Print	Prints a full-page diagram of the right-clicked connection.
Cancel	Dismisses the pop-up menu.

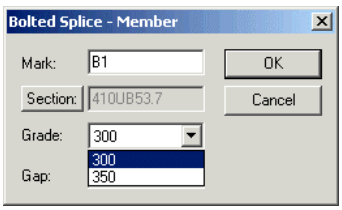
4:Technical Notes

Default Data

When you select a new connection in Limcon default values will appear for each parameter so that no additional data input is required to define a complete connection. In many cases the default data corresponds to worked examples in the reference documents. Default sections change with the country setting so that they may be found in the usual section library for the particular country. For example, the default beam section for the FEP connection is W16X36 for US, W410X54 for Canada, UB406X178X54 for UK, IPE400A for Europe, and 410UB53.7 for Australia and New Zealand. These sections are found in the library files Aisc.lib, Cisc.lib, Uk2000.lib, Euro.lib, Asw.lib, respectively.

Steel Grades

Limcon permits the input of the *grade* of steel sections and plate components. The yield stress and ultimate stress are automatically determined by Limcon according to the applicable standard.



Section Grades

The section library contains the names of steel grades available for each section. When you choose a section you must also choose a steel grade from those available. You may change grade availability by editing the section library but only recognized grades should be used.

When the grade names contained in the library are not suitable, you may select International in the General Configuration dialog box. This allows you to choose any known grade, whether its name is in the library or not.

Plate Component Grades

Limcon offers different grades for plates depending on the country configuration setting. These grades are shown in the table below. As an alternative to selecting one of these grades you may specify the yield and ultimate stresses for the plate material, provided this option is enabled in the General Configuration dialog box. You may select International in this dialog box to enable selection of other plate grades.

International

When International is selected in the General Configuration dialog box a wide range of section and plate grades are available. These include all the grades in the table below plus several others, including the Japanese grades to JIS G 3101 and JIS G 3106, and the Chinese grades Q235 and Q345.

Item	US Grades*	Canadian Grades	UK/Eurocode Grades	Aust./NZ Grades†
Hot-rolled sections	A36, A588, A992	260W, 300W, 350W	S235, S275, S355, S450, S460, 43, 50, 55	250, 300, 350, 400
Welded sections		260W, 300W, 350W		250, 300, 350, 400, 450, 300M
Hollow sections	A501, A500-B, A500-C, A53	300WH, 350W, 400W	S275, S355, S450, S460, 43, 50, 55	C250, 345, C350, C450
Cleats, plates, stiffeners	A36, Gr.42, Gr.50	260W, 300W, 350W, 400W	S235, S275, S355, S450, S460, 43, 50, 55	250, 300, 350, 250+, 300+, 350+

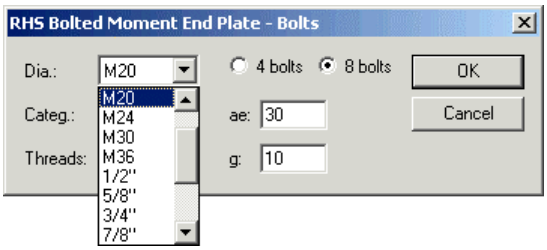
* US Plate Grades
Grades 42 and 50 may be used instead of particular ASTM grades. Gr.42, referred to in Limcon as “US42” has a yield stress of 42 ksi and an ultimate tensile stress of 60 ksi. Gr.50, referred to as “US50” has a yield stress of 50 ksi and an ultimate tensile stress of 65 ksi.

† AS/NZS Plate Grades
Grades 250, 300, and 350 are to AS/NZS 3678 while 250+, 300+, and 350+ are to AS/NZS 3679.1. Usually, only grades 250 and 300+ are available but you can enable the extra grades by selecting the AS/NZS plate grades option in the General Configuration dialog box.

Bolts

Bolt Diameter

Metric bolts ranging from M12 to M36 are available in the bolt diameter list box for all country settings. The “Extra bolts” configuration item is provided to include M22 and M27 bolts, which are not preferred sizes, and the larger bolts that may be required in base plates. When the country setting is US or Canada, US customary sizes ranging from ½” to 1 ½” are added to the list box after the metric sizes. With “Extra bolts” selected, bolt sizes larger than 1 ½” are added.



Bolt Categories

Bolt categories are specified by design codes. Those recognized by Limcon are shown in the following table.

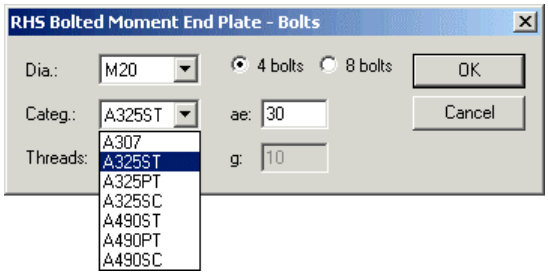
Type	Bolt Categories			
	US/Canada	UK	Eurocode	Aust./NZ
Snug-tightened	A307 A325ST A490ST	4.6 8.8 10.9	4.6A 5.6A 8.8A 10.9A	4.6/S 8.8/S
Tensioned	A325PT A490PT	FG/B FH/B	8.8E 10.9E	8.8/TB
Friction	A325SC A490SC	FG/NSS FG/NSF† FH/NSS FH/NSF†	8.8B 8.8C† 10.9B 10.9C†	8.8/TF F10T*

* F10T is a grade 10.9 friction bolt category to Japanese standard JIS B 1186.

† Non-slip at ultimate.

The country setting and connection type determine which bolt categories are available.

Friction (i.e. slip critical) bolts are not available for all connection types. They may be selected for the bolted splice (BSPL), bolted flange plate connection (FPC), and the most common shear connections (WSP, FEP, ACLT).



When the bolt diameter exceeds 1 ½" selected ASTM bolt categories are automatically displayed in output as follows:

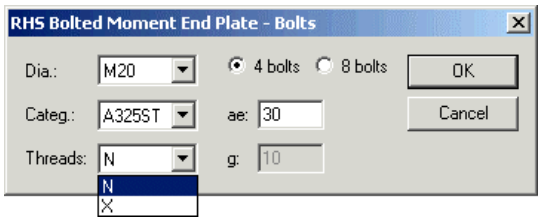
A307 → A36
A325 → A449
A490 → A354BD

International

When International is selected in the General Configuration dialog box all bolt categories are available.

Threads In the Shear Plane

Select N when threads are iNcluded in the shear plane or X if they are eXcluded.



Bolt Bearing

Bolt bearing capacity as defined by design codes is the lesser of the bearing and tearing strengths of the ply or part. Limcon shows the capacities for bolt bearing and tearing separately and the lower value governs.

ANSI/AISC 360

In ANSI/AISC 360 equation J3-6a applies when "deformation of the bolt hole at service load is a design consideration" and equation J3-6b applies otherwise. By default, Limcon uses the more conservative equation J3-6a. There is an option in General Configuration to use equation equation J3-6b instead. Cl. J3.10 allows bearing resistance to be calculated as the sum of the bearing resistances of the individual bolts. This provision is

implemented for concentrically loaded bolt groups, e.g. BRAC, FEP, FPC, and BSPL flange splices.

BS 5950

Ply bearing must be checked for bolts that are "non-slip in service" but Cl. 6.4.1 permits an increase of 50% in the bearing capacity permitted by Cl. 6.3.3.3. Thus, bearing capacity in many connections can be increased by specifying this type of friction bolt.

According to the same clause, bolts that are "non-slip under factored loads" do not have to be checked for bearing at all. This type of friction bolt is checked for bearing in Limcon with a 100% increase in the bearing capacity permitted by Cl. 6.3.3.3.

EC3

This code, like ANSI/AISC 360, allows bolt bearing resistance to be calculated as the sum of the bearing resistances of the individual bolts, but only if the bearing resistance exceeds the bolt shear resistance for every bolt in the group. This provision is implemented for concentrically loaded bolt groups, e.g. BRAC, FEP, FPC, and BSPL flange splices.

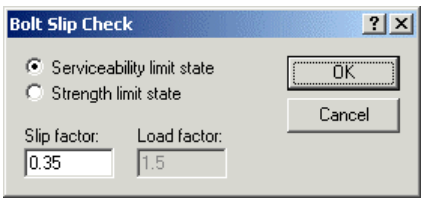
AS 4100 and NZS 3404

The rules in AS 4100 and NZS 3404 allow much greater bolt bearing capacity than do other steel design codes. In order to mobilize the stated capacity unacceptable deformations may occur (Ref. 32). As a result, bolt groups with a single row of bolts loaded in tension may be designed unconservatively using the rules of AS 4100 or NZS 3404. Bracing cleat connections could fall into this category and accordingly, when checking single row bolt groups subject to tension in this connection type, Limcon uses a bolt bearing capacity factor of 0.75 instead of 0.9.

Friction Bolts

Friction (i.e. slip critical) bolts are available for the bolt group (BGP), bolted splice (BSPL), bolted flange plate connection (FPC), and the most common shear connections (WSP, FEP, and ACLT). When friction bolts are selected for one of these connection types Limcon automatically performs a slip check for each bolt group in the connection.

When you specify friction bolts for any connection you may also specify the bolt slip factor by clicking the adjacent Slip Check button. This will display the Bolt Slip Check dialog box shown below.



ANSI/AISC 360

Whether Limcon is configured for ASD or LRFD you may choose the serviceability or strength limit state. Limcon checks the slip resistance determined from the code against the input load effects, service loads for ASD and factored loads for LRFD.

BS 5950

BS 5950 has friction bolt categories that are either non-slip in service or non-slip at failure (NSF). In both cases, the check is performed using factored load effects. The serviceability limit state is presented as an ultimate limit state – the code specifies different strengths for the two conditions.

EC3

EC3 has friction bolt categories that are either "slip-resistant at serviceability" (B) or "slip-resistant at ultimate" (C). In both cases, the check is performed using factored load effects. The serviceability limit state is presented as an ultimate limit state – the code specifies different strengths for the two conditions.

CAN/CSA-S16

You may specify either the serviceability or strength limit state. For the serviceability limit state the load effects are determined from the strength/service load factor, which must be input. A typical value is 1.5.

AS 4100 and NZS 3404

Bolt slip is a serviceability limit state in these codes. The load effects are determined from the strength/service load factor, which must be input. A typical value is 1.5. Limcon also allows bolt slip to be checked as a strength limit state.

IC Method

Even though the IC method may be used for the strength check in eccentrically loaded bolt groups, bolt forces for the slip check are always determined using the elastic method.

Out of Plane Forces

The support bolt group in the flexible end plate (FEP) and angle cleat (ACLT) connections may be subject to both in-plane and out-of-plane forces. It is assumed that tension in the beam reduces the slip resistance of these bolt groups linearly to zero at the point where the bolt pretension is entirely counteracted by the axial tension (see Ref. 24, p. 341). Compression is assumed to have no effect on the slip resistance.

Welds

The dialog box below is used for choosing the welds in the welded beam/column connection (WBC) and is typical of many others.

fu:

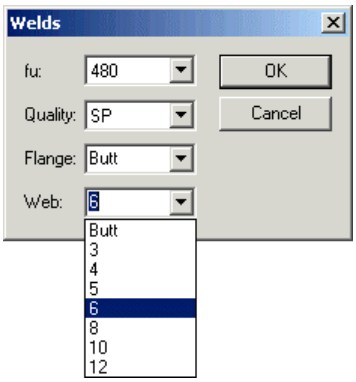
The ultimate strength of the weld material, MPa or ksi. When the configured design code is EC3 this value is not used, the weld resistance being determined by the base metal strength.

Quality:

Usually all welds are “SP”. When AS 4100 or NZS 3404 is the design code “GP” may be chosen for a lower quality weld (fillet welds only).

Size:

A drop-down list box shows all available fillet weld sizes and an item for a full penetration butt weld (FPBW) or complete joint penetration groove weld (CJPGW).



When ANSI/AISC 360 is the design code complete joint penetration groove welds do not have to be checked because the strength of the joint is controlled by the base metal. The strength of a complete joint penetration groove weld should never govern.

Directional Strength of Fillet Welds

ANSI/AISC 360 and CAN/CSA-S16 permit a 50% strength increase for fillet welds loaded at right angles to the length of the weld. BS 5950 and EC3 permit a directional strength increase of 25% and 22%, respectively. When Limcon is configured for these codes the additional strength is used for fillet welds in some connections, e.g. for fillet welds between a beam flange or flange plate and a column flange. Limcon output always shows an advisory note when the directional strength increase is utilized.

Directional strength increase is not used when Limcon is configured for AS 4100 or NZS 3404.

Weld Matching

Limcon implements code provisions related to weld matching for fillet welds in some connections. For ANSI/AISC 360 weld leg shear yield and shear rupture are checked while for CAN/CSA-S16 only weld leg shear rupture is checked. For BS 5950 Limcon uses the Table 37 weld design strengths, which are limited for unmatched welds. EC3 does not specify weld metal strength checks because requirements for electrodes ensure that welds are matched. AS 4100 and NZS 3404 specify compliance with AS/NZS 1554.1, which has provisions ensuring that welds are matched.

HSS Welds

Welds are represented as accurately as possible in the virtual reality window. In the case of HSS truss connections, each weld element is represented diagrammatically as a sector of a cylinder, whose radius equals the throat dimension, centered on the outside edge of the intersecting HSS. The exact welding details for these connections may be quite complicated, varying around the perimeter of each HSS from a fillet weld to a full or partial penetration weld

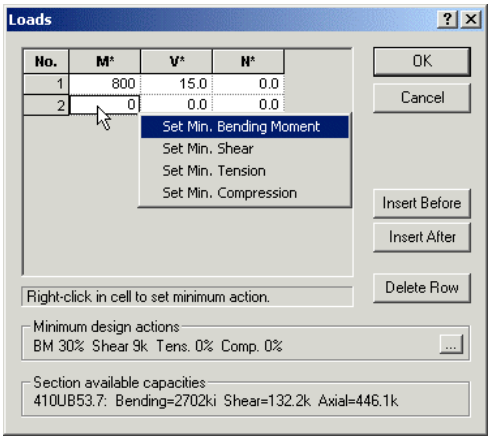
The design of welds in HSS truss connections is not straightforward. See References 25, 52, 53, and 54 for more information. In checking the welds in the overlapped K/N connection (TKNO), Limcon makes these simplifying assumptions:

- For brace 1 the effective length of the weld may be obtained by linear interpolation between the length for zero and the length for 100% overlap.
- For brace 2 the force on the weld may be obtained by linear interpolation between the force for zero and the force for100% overlap.

Multiple Load Cases

From V3.5, Limcon permits multiple load cases for some connection types. These are the same connection types that may be used when Limcon is used in conjunction with a structural analysis program, such as Microstran. A dialog box for entering multiple load cases is shown below.

Minimum design actions may be set by right-clicking on a load component cell in any load case. The pop-up menu contains items for setting each type of minimum action. Limcon will not permit choice of an inapproriate action – e.g. you cannot choose minimum shear when you right-click in an axial force cell. The minimum action is set according to the values shown at the bottom of the dialog box. Clicking the "**…**" button gives immediate access to the **File > Configure > Minimum Actions** command.



LOADS DIALOG BOX FOR BOLTED SPLICE

Note: Limcon evaluates each load case in turn, displaying a table of applied loads with the corresponding strength ratio and utilization ratio. The critical load case, the one with the lowest strength ratio and highest utilization ratio, is identified in this table. The detailed Limcon output that follows the table applies only to the critical load case. If you wish to see detailed output for a non-critical load case you can make a copy of the connection and delete all cases except the one of interest.

LRFD and ASD

Limcon V3.6 supports the ANSI/AISC 360 steel design specification, which integrates the LRFD and ASD design methods. Earlier versions of Limcon support the LRFD design method as specified in the AISC LRFD 1999 edition.

Essentially, the difference in Limcon between LRFD and ASD is that loads for LRFD are *factored* loads while those for ASD are *service* loads (refer to ANSI/AISC 360 Cl. B2, where SEI/ASCE 7 Section 2.3 is specified for LRFD load combinations and Section 2.4 for ASD). Whether LRFD or ASD is used, Limcon computes an available strength for each limit state and compares it to the required strength.

Note: To express the result of each limit state check Limcon uses the *strength* ratio or *load factor*. This is the ratio of the available strength to the required strength and the minimum strength ratio for all limit states must not be less than 1.0. Limcon also uses the alternative *utilization ratio*, which is the reciprocal of the strength ratio and is usually expressed as a percentage. The maximum utilization ratio for all limit states must not exceed 100%. You may configure Limcon to your preference, to emphasize either the strength ratio or the utilization ratio in reports.

The first part of the strength check output for a shear end plate connection (FEP) is reproduced below for LRFD and ASD design methods. In both cases, the result of each limit state check is shown with a strength ratio. The design shear force is 50 kips for the LRFD design while the service shear force is 35 kips for the ASD design. As would be expected, the respective strength ratios, which depend on the relative values of the design load and the service load, are very similar for the two methods.

```
DESIGN STRENGTH CHECKS...
                                                Strength ratio --------+
                                                Reqd. strength -+      |
                                             +-- Design strength |      |
                                             |                  |      |
CHECK 2 - Weld:
 Weld shear capacity . . . . . .  .  .  .  .   94.7  >  Vu   =   50.0  1.89  Pass

CHECK 3 - Bolts:
 Bolt shear capacity . . . . . .  .  .  .  .   95.1  >  Vu   =   50.0  1.90  Pass
 Plate ply bearing capacity  . . . . . .  .   183.5  >  Vu   =   50.0  3.67  Pass
 Plate ply tearing capacity  . . . . . .  .   133.8  >  Vu   =   50.0  2.68  Pass

CHECK 4 - Plate:
 End plate shear capacity  . . . . . .  .  .   91.1  >  Vu   =   50.0  1.82  Pass
 Plate block shear . . . . . .  .  .  .  .  .   98.9  >  Vu   =   50.0  1.98  Pass
```

LRFD STRENGTH CHECKS USING STRENGTH RATIO

```
ASD STRENGTH CHECKS...
                                                  Strength ratio --------+
                                                  Reqd. strength -+      |
                                               +-- ASD strength    |      |
                                               |                   |      |
CHECK 2 - Weld:
 Weld shear capacity . . . . . . . . . . . .    63.2  >  V     =   35.0  1.80  Pass

CHECK 3 - Bolts:
 Bolt shear capacity . . . . . . . . . . . .    63.4  >  V     =   35.0  1.81  Pass
 Plate ply bearing capacity  . . . . . . . .   122.3  >  V     =   35.0  3.50  Pass
 Plate ply tearing capacity  . . . . . . . .    89.2  >  V     =   35.0  2.55  Pass

CHECK 4 - Plate:
 End plate shear capacity  . . . . . . . . .    60.6  >  V     =   35.0  1.73  Pass
 Plate block shear . . . . . . . . . . . . .    65.9  >  V     =   35.0  1.88  Pass
```

ASD STRENGTH CHECKS USING STRENGTH RATIO

The strength check output is repeated below showing the utilization ratio instead of the strength ratio.

```
ASD STRENGTH CHECKS...
                                                  Utilization ratio -----+
                                                  Reqd. strength -+      |
                                               +-- ASD strength    |      |
                                               |                   |      |
CHECK 2 - Weld:
 Weld shear strength . . . . . . . . . . . .    63.2  >  V     =   35.0   55%  Pass

CHECK 3 - Bolts:
 Bolt shear strength . . . . . . . . . . . .    63.4  >  V     =   35.0   55%  Pass
 Plate ply bearing strength  . . . . . . . .   122.3  >  V     =   35.0   29%  Pass
 Plate ply tearing strength  . . . . . . . .    89.2  >  V     =   35.0   39%  Pass

CHECK 4 - Plate:
 End plate shear strength  . . . . . . . . .    60.6  >  V     =   35.0   58%  Pass
 Plate block shear . . . . . . . . . . . . .    65.9  >  V     =   35.0   53%  Pass
```

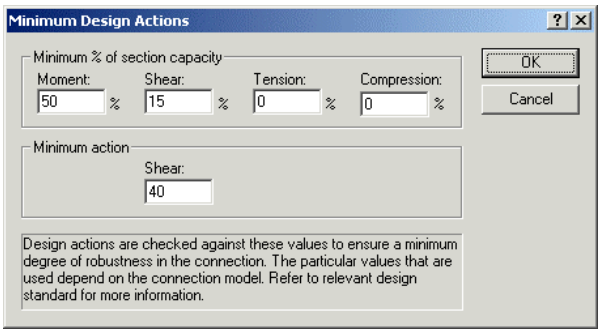
ASD STRENGTH CHECKS USING UTILIZATION RATIO

Minimum Design Actions

To ensure a certain minimum degree of robustness in a connection, design codes and connection models may specify minimum design actions. For shear and axial force it may be an absolute value in kN (metric) or kips (US units), while for bending, it may be specified as a percentage of the member capacity. Limcon permits input of a percentage of section capacity for all actions and an absolute value for shear.

In general, there is insufficient information available for Limcon to know *member* capacities, so *section* capacities are used with the specified percentages.

The **File > Configure > Minimum Actions** command displays a dialog box in which you may specify minimum actions. These values are part of Limcon's configuration data and they are used for the current job, regardless of the values that were in effect when that job was last saved. This facilitates the review of any Limcon job against revised minimum design actions.



MINIMUM DESIGN ACTIONS

For many connections Limcon checks whether input loads are sufficient to satisfy the specified minimum actions and displays a warning where they do not. In versions prior to V3.5, Limcon automatically increased input loads to match specified minimum actions.

ANSI/AISC 360

This code has no specific rules on minimum design actions but Ref. 6 suggests that non-seismic end plate connections should be designed for at least 60% of the beam strength, while moment splices located at the point of minimum moment should be designed for at least 1/6 of the member strength. The ANSI/AISC 360 Commentary recommends a general minimum load of 10 kips (LRFD) or 6 kips (ASD), which is applicable to shear connections and truss (axial) connections. Beam load tables may be used to ensure that shear connections are designed for the maximum uniform load that can be supported by the beam.

CAN/CSA-S16

This code has no specific rules on minimum design actions. Beam load tables may be used to ensure that shear connections are designed for the maximum uniform load that can be supported by the beam.

BS 5950

This code has no specific rules on minimum design actions but Ref. 9 suggests that flange welds in moment connections should be full-strength. Beams that have to be designed for the structural integrity tying force must have the necessary strength (at the strength limit state) to resist an axial load of at least 75 kN. This requirement would ensure a substantial shear capacity.

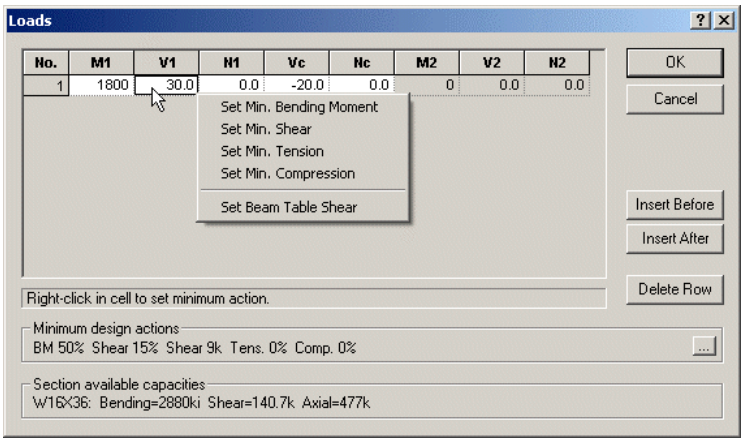
EC3

This code has no specific rules on minimum design actions.

AS 4100 and NZS 3404

These codes mandate a minimum design shear of 40 kN and a minimum design moment of 50% *of the member moment capacity* (but 30% for splices). Splices are preferably located at points where bending moment is low. The apex connection in a portal frame should be classified as a moment connection requiring the 50% minimum, not as a splice requiring 30%.

As shown below, load dialog boxes allow you to right-click on load components and select the minimum load. Limcon then calculates the minimum action and inserts this value in the right-clicked grid cell.



SETTING MINIMUM ACTIONS

Shear Connections

Axial Force

The most common shear connections (WSP, FEP, ACLT) may be checked for axial force as well as shear. The ASI models for these connections do not cover axial forces. Tension in these connections is checked according to American practice, as set out in Ref. 6.

When considering axial force Limcon assumes that the connection is concentric with the beam axis.

Bolt Groups

Bolt groups are checked for axial force except for compression in the flexible end plate connection (FEP).

Buckling

Buckling is considered when the web side plate connection (WSP) is in compression. It is assumed that the plate is fixed at the weld and at the first column of bolts with sidesway permitted. As the flexural stiffness of the plate is negligible compared to the weak axis flexural stiffness of the beam it is assumed that there is no eccentricity moment in the plate.

Buckling is not considered for angle cleat (ACLT) or flexible end plate (FEP) connections.

Beam Copes

Beams connected to the web of another beam may have single or double web copes to provide clearance to the flanges of the support beam. When connection to a beam web is specified clearance checks are automatically performed. No clearance checks are done for beams connected to a column flange. When the support is a column web Limcon warns if flange copes are necessary but they are ignored in capacity calculations and in the virtual reality view.

The limit state of coped web local buckling is evaluated according to the Cheng, Yura, Johnston method (Ref. 6, p. 9-6). This check is informative for BS 5950, AS 4100, and NZS 3404, because the British and Australian design models (References 10 and 34, respectively) specify geometric limits within which local buckling is deemed not to occur.

Structural Integrity Tying Force

When the axial force is a structural integrity tying force BS 5950-1:2000 Cl. 2.4.5.2 allows it to be checked independently of the shear force. For flexible end plate and double angle cleat connections any load case with axial tension only is checked in Limcon as a structural integrity condition using the large displacement analysis method of Ref. 10. It is the responsibility of the designer to include the structural integrity tying force if required – Limcon does not include it automatically.

Single Plate / Shear Tab / Fin Plate / Web Side Plate (WSP) Connection

Fillet Weld Size

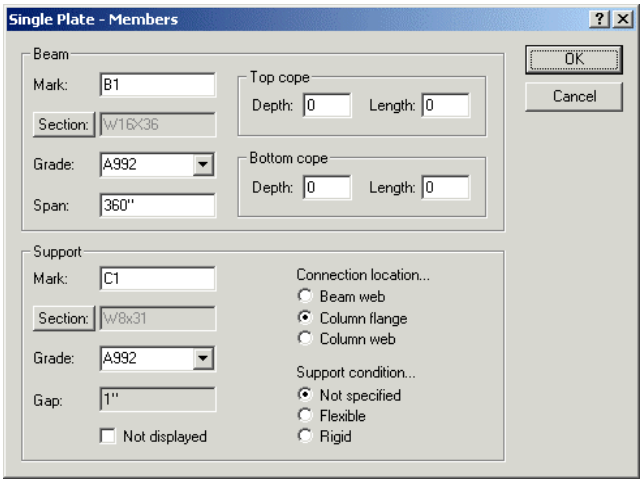
Design models for this connection specify a minimum fillet weld leg dimension to ensure that the cleat yields before the weld fractures. Limcon uses the minimum weld sizes shown in the table below.

Design Code	Minimum Fillet Weld Leg	Reference
ANSI/AISC 360	62.5% of plate thickness*	6
CAN/CSA S16	75% of plate thickness	8
BS 5950-1:2000	80% of plate thickness	10
AS 4100 / NZS 3404	75% of plate thickness*	35

* Weld of minimum size does not need to be checked.

Flexible/Rigid Support Condition

When a flexible support condition is specified it is assumed that the moment on the *weld group* is zero. Similarly, when a rigid support condition is specified it is assumed that the moment on the *bolt group* is zero. If the support condition is not specified it is assumed that the maximum bending moment acts on both the weld and the bolt group. While a column flange connection could be rigid and a beam web connection could be flexible, tests show that accurately predicting the eccentricity is not always possible.



SPECIFYING THE SUPPORT CONDITION

Note: When Limcon is configured for AS 4100 or NZS 3404 the support condition should be "not specified" because the ASI design model (Ref. 37) does not permit the distinction between flexible and rigid support conditions.

Extended Plate

When the distance from the face of the support to the first line of bolts exceeds a specified value (e.g. 3.5 in. for the AISC design model) a buckling check is performed on the plate. In accordance with the recommendations of Ref. 6, this is done using the Cheng, Yura, Johnston method for checking local buckling in a double-coped web.

HSS Column

Unlike other shear connections, this connection is available in Limcon with hollow structural section (HSS) columns. Punching shear of the plate is checked and without axial force in the beam it is not necessary to check for column face yielding (Ref. 25, p. 312). When axial force is present Limcon checks column face yielding assuming that the effect of compressive stresses in the column is negligible. This check may be performed by treating the connection as a single brace connection (BRAC), in which the additional column actions are taken into account. See "Hollow Structural Section Chord/Column Face Yielding" on p. 64.

Rigid Connections

Analysis Method

The distribution of forces between the flanges and web in BSPL, WSPL, BMEP, HBEP, and WBC connections is determined by the analysis method set with the **File > Configure > General** command. There are three different methods – these are *simplified, elastic*, and *plastic*. The analysis method selection does not affect the AISC moment end plate (MEPC) and flange plate (FPC) connections because the simplified method is intrinsic to these connection models.

The **simplified method** is a traditional approach for the design of splices in which the flange plates are assumed to resist all the moment and axial force while the web plates resist the shear (and the resulting eccentricity moment). This is the default method in Limcon.

The **elastic method** was recommended in Ref. 11 and it is optional in the updated *ASI Connections Series* (References 41-44). It is recommended for splices in the AASHTO 1999 Interim.

The **plastic method** is the only method giving a rational stress distribution when the factored loads are sufficient to cause yield. The other analysis methods may then produce flange forces that exceed the capacity of the flange.

Choosing either the elastic or plastic analysis method for a splice generally produces designs with smaller flange plates and larger web plates.

The choice of analysis method does not affect the checking of bolts in BMEP and HBEP connections. Even though the flange force varies with the analysis method, the bolts must be checked for forces that are statically equivalent to the design actions.

Web Fillet Welds

Web fillet welds in BMEP, HBEP, and WBC connections are checked using one of two methods.

1. Where the elastic or plastic analysis method is used the beam web weld is checked by the linear elastic method, which may be very conservative, leading to a required weld size exceeding the thickness of the web. *Specifying web fillet welds with a size exceeding the thickness of the web is almost certainly wasteful.*
2. Where the simplified analysis method is used the web weld is checked using the method from Ref. 18, in which the compression part of the web weld is assumed to resist all the shear while the tension part must have sufficient tension strength to match that of the beam web. This method is also used in References 19 and 41-44.

The welded splice (WSPL) web plate weld is always checked using the linear elastic method, taking into account the eccentricity of the shear force from the centroid of each weld group.

Section Bending/Axial Check

In general, a check on the section at the connection location could be considered to be part of the member design and therefore not necessary in the connection design context. For bolted splices (BSPL) and bolted flange plate connections (FPC), however, the section is checked in Limcon because of the presence of bolt holes. Checking the flanges is a convenient alternative to the application of code rules for determining section capacity in members subject to combined actions but the flange forces must be computed rigorously (i.e. with the plastic analysis method). A check with simplified analysis flange forces will certainly fail when the applied load approaches the section strength. In previous versions of Limcon such flange checks were made informative so that they did not govern the design.

For the bolted splice the critical location for the section bending/axial check is the outermost flange bolt row where the bending moment may exceed the specified design moment – see “Bolted Splice (BSPL)” on p. 56.

Bolted Splice (BSPL)

Full Contact

For the bolted splice, you may enter a value for the gap between the ends of the connected members. When this value is zero the members are considered to be prepared for full contact and compressive actions are resisted by bearing on contact surfaces. An additional condition must then be considered – the minimum force acting on plates and connectors. For this force AS 4100 adopts a value of 15% of the member capacity in compression. Limcon does not perform this check automatically. The requirement can be satisfied by an additional load case containing a *tension* force only.

Friction Bolts

A bolt slip check is performed with friction bolts only. For ANSI/AISC 360 the check may be at service loads or factored loads. For BS 5950 and EC3 the check is determined by the bolt category. For AS 4100 and NZS 3404 the check is usually at service loads. The strength ratio or load factor (LF) is used to determine the service load from the ultimate load. A typical value for LF is 1.5.

Flange/Plate Net Section Rupture

Flange and plates in tension are checked for rupture on the net section at the outer bolt row. Where the splice must be checked for high shear and moment concurrently, variation of the moment over the length of the splice could mean that the moment specified at the center is inadequate for the net section checks. By default, Limcon increases the moment for the net section checks by the product of the shear force and the distance from the center of the splice to the outer bolt row. There is an option in the General Configuration dialog box to avoid this behaviour – selecting it necessarily means that the input moment is the maximum that occurs over the length of the splice.

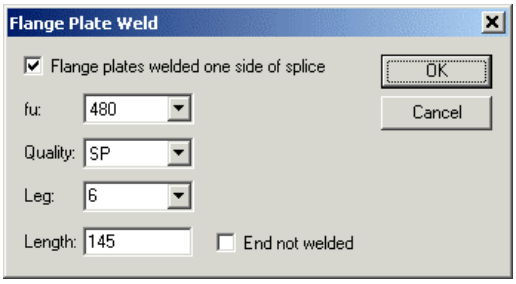
Inner Flange Plates

In the Plates dialog box there is an option to specify inner flange plates. For an I section this adds two identical plates of the same length as the outer plate. The flange force is apportioned in the ratio of the gross area of outer and inner plates and each plate connection is checked independently.

Flange Plate Weld

There is an option for the flange plates to be fillet welded and not bolted on one side of the splice. The detail shows one set of flange plate welds on each side of the splice; i.e. bottom left and top right flanges welded, bottom right and top left flanges bolted. Flange plates are located so that the welded end overlaps the flange by exactly the specified weld length.

The dialog box for inputting the flange plate weld also permits the omission of the end welds. This allows the designer to avoid transverse welds, which in some situations may cause flange embrittlement or otherwise impair flange strength.



FLANGE PLATE WELD DIALOG BOX

Shear Lag

Shear lag is checked when a tension flange plate is connected by longitudinal welds only. In this case Limcon enforces a minimum length of weld equal to the width of the plate (L/w = 1.0). Where the design code does not specify the shear lag coefficient the value from Ref. 25 is used – this varies from 0.75 when L/w is 1.0 to 1.0 when L/w is 2.0.

ASI Bolted Moment End Plate Connection (BMEP, HBEP)

Note: Moment end plate connections may be designed as a thin plate with strong bolts or a thick plate with weaker bolts. With "thin plate" behaviour bolt efficiency is reduced by bolt prying forces but with "thick plate" behaviour bolt prying forces are negligible. The transition from thin plate to thick plate behaviour is taken as the plate thickness at which plate yield strength exceeds bolt rupture strength by 11% (Ref. 18).

The bolted moment end plate (BMEP) and haunched bolted end plate connection (HBEP) were originally based on Ref. 11. This model used a simple 1-dimensional yield line analysis with prying assumed to add 30% to the bolt forces that would be necessary without prying. The model is widely regarded as excessively conservative because the necessary end plate thickness ensures minimal bolt prying forces. In fact, when end plates are connected to thin column flanges prying forces of the magnitude of those assumed in the model may exist, even when transverse stiffeners are present.

In 2009 the BMEP and HBEP connections were revised in accordance with the new *ASI Connections Series* (References 41-44), which replace Ref. 11. These new publications are based on the AISC Design Guide No. 4, *Extended End Plate Moment Connections – Seismic and Wind Applications – 2nd Edition* (Ref. 19), which requires thick plate/flange behaviour, and AISC Design Guide No. 16, *Flush and Extended Multiple Row Moment End Plate Connections* (Ref. 18), which does not. Thick plate behaviour is necessary in seismic design because the "strong column / weak beam" requirement demands that moment connections remain elastic under seismic excitation.

Limcon allows you to select thick plate/flange behaviour when required. Substantial economies may be achieved in non-seismic designs by not requiring thick plate/flange behaviour. For example, expensive welded flange doubler plates can sometimes be avoided if thick flange behaviour is not necessary.

As shown in the table below, the new BMEP and HBEP connections permit several new multiple bolt row arrangements, e.g. 2 bolts outside the tension flange with 4 or 6 inside. End plate stiffeners are permitted for two types of BMEP connection only.

No. Bolt Rows		End Plate Stiffener	Ref.	Comment
Outside Flange	Inside Flange			
0	1	–	18	Flush, non-seismic*
0	2	–	18	Flush, non-seismic*
0	3	–	18	Flush, non-seismic*
1	1	–	18, 19	Extended, seismic
1	1	Yes	18, 19	Extended, seismic
1	2	–	18	Extended, non-seismic
1	3	–	18	Extended, non-seismic
2	2	Yes	19	Extended, seismic
1	0	–	–	Extended, non-seismic*

* Not included in ASI models.

The arrangement with a bolt row outside the flange and none inside is intended for small beams where there is insufficient space for a bolt row inside the flange.

Snug-tightened bolts are not permitted with these connections.

AISC Moment End Plate Connection (MEPC)

The AISC Steel Design Guide 16 *Flush and Extended Multiple Row Moment End Plate Connections* (Ref. 18) sets out design models for both flush and extended end plate moment connections with multiple bolt rows. The models, which rely on 2-dimensional yield-line analysis, were verified by full-scale tests. Limcon implements all five unstiffened connections and the two stiffened extended end plate connections.

The applicability of the connection design models is specifically limited to I sections meeting certain geometric requirements. These limits significantly restrict the number of I sections with which the flush end plate may be used.

Only high-strength bolts may be used. It has been determined by tests on large moment end plate connections that the strength is not adversely affected by the use of snug-tightened bolts (Ref. 18). The design procedure permits use of snug-tightened Grade 8.8 and A325 bolts. Higher strength bolts must be fully tensioned.

Note: Snug-tightened bolts must not be used with this connection for dynamic loading or in areas of high seismicity.

Axial Load Treatment

The tests on which the connection design model is based did not include axial forces – this is primarily a flexural model. The connection is not suitable for checking of base plates because many of the limit states relevant to base plates are not checked.

Axial forces are permitted by use of the procedure recommended in Ref. 18 to "convert the factored axial load into an equivalent moment that will be added to the factored connection moment for axial tension or subtracted from the factored connection moment for axial compression". Limcon limits the axial load equivalent moment so that one flange remains in compression.

Strength Limit States

The diagram below shows a plot of the strength ratio for the example on p. 43 of Ref. 18 with the end plate thickness varied above and below the specified thickness of 9/16" (14.3 mm). The diagram shows the three possible failure modes predicted by the design model:

A – End plate yield (thin plate behaviour).

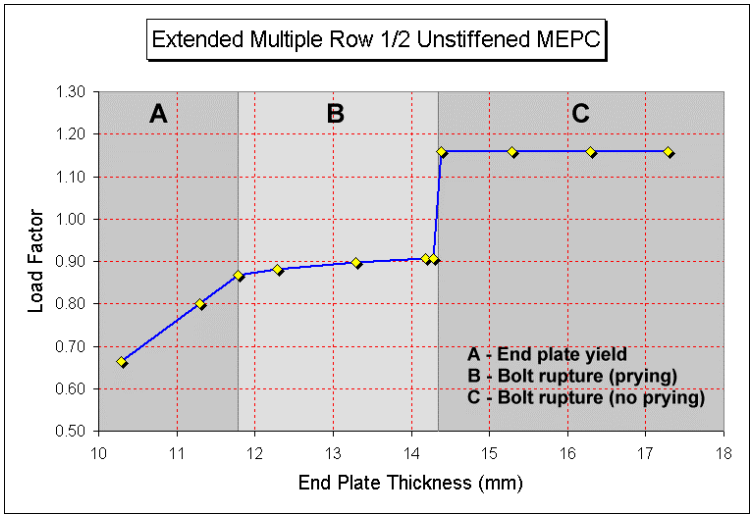
B – Bolt rupture with prying (intermediate plate behaviour).

C – Bolt rupture without prying (thick plate behaviour).

When the plate thickness is such that mode A behaviour occurs, maximum prying forces exist but have no effect on the connection capacity because it is determined by plate yielding. With mode C behaviour there are no prying forces and the capacity of the connection is determined by the bolt strength. Throughout the range of plate thicknesses that lead to mode B behaviour, prying forces vary from a maximum at the A/B thickness to zero at the B/C thickness. The

connection capacity is adversely affected by the bolt prying forces in this range only.

The design model assumes the maximum prying force whenever prying exists and this accounts for the discontinuity in connection capacity at the B/C thickness, which would not occur in reality.



STRENGTH RATIO VS. END PLATE THICKNESS

Limcon can readily be used to optimize the connection design for either thinner end plate and larger bolts (end plate yield) or thicker end plate and smaller bolts (bolt rupture).

Column-Side Checks

In beam/column connections the column and stiffeners, if present, must be checked for limit states such as column flange bending and column web panel zone shear, to name just two.

Column-side checks were performed according to Ref. 11 (now obsolete) for BMEP, HBEP, and WBC connections only. With the introduction, in 2009, of the new ASI Connections Series (References 42, 43), column-side checks became available for all beam/column connections:

- BMEP, HBEP – bolted moment end plate connection
- WBC – welded beam/column connection
- MEPC – moment end plate connection
- FPC – bolted or welded flange plate connection

The latest AISC recommendation on column stiffening for welded connections are found in AISC Steel Design Guide 13, *Stiffening of*

Wide Flange Columns at Moment Connections: Wind and Seismic Applications (Ref. 20). These are adopted in Limcon for the WBC and FPC connections.

For bolted end plate connections there are more recent recommendations in AISC Steel Design Guide 4, *Extended End Plate Moment Connections – Seismic and Wind Applications – 2nd Edition* (Ref. 19). These are adopted in Limcon for the BMEP, HBEP, and MEPC connections. This publication contains two requirements that are not included in the superseded requirements of Ref. 20:

- Thin plate behaviour of the column flange is not permitted. If you elect to enforce thick plate behaviour Limcon will fail any BMEP, HBEP, or MEPC connection where thin plate behaviour is found to occur. To ensure thick plate behaviour of the column flanges you may choose a column with thicker flanges, or in the case of the BMEP and HBEP connections, you may add column flange doubler plates. When the thick plate model is not enforced prying is assumed to reduce bolt efficiency by 20%.
- Even though tension flange stiffeners (continuity plates) may be provided there is still a requirement to check column flange bending using a 2-dimensional yield line analysis. This check is performed in Limcon.

Column Web Doubler Plates

Web doubler plates may be used in beam/column connections "to enhance the capacity of the column web to resist compressive force from a beam flange or to resist shear force". They are discussed in Ref. 11 on p. 194. It is stated that the column web doubler plate must extend beyond the flanges of the beam by a distance of at least the column depth or 12 times the column flange thickness.

The extension of the web doubler plate beyond the extremities of the connected beams envisages use of the web doubler without co-existing stiffeners adjacent to the beam flanges. Web doubler plates are commonly enclosed by top and bottom stiffeners adjacent to the beam flanges and do not extend past the beam flanges.

Limcon permits web doubler plates on one or both sides of the column as an alternative to shear (diagonal) stiffeners provided they are accompanied by top and bottom stiffeners. There is a full penetration butt weld all around the web doubler plate, either to column flanges or column flange doubler plates on the sides and stiffeners on the top and bottom. The length (height) of the doubler plate is computed by Limcon as the clear distance between top and bottom stiffeners less 12 mm. Where there are no flange doubler plates, the width of the doubler plate is the depth of the column web between fillets. Where there are full-length flange doubler plates on one or both column flanges the web doubler plate width is computed as the lesser of the column web depth

between fillets and the clear distance between flange doublers less 6 mm for each full-length flange doubler.

When web doubler plates are used you should carefully consider the welds required at the side of each top and bottom stiffener. Although Limcon permits tension stiffeners with no side welds, this is not satisfactory if a web doubler plate is butt-welded to it.

Column Flange Doubler Plates

For BMEP and HBEP connections doubler plates may be used to reinforce column flanges that would otherwise be too thin to resist flange bending. Limcon originally implemented column flange doubler plates in accordance with Ref. 11 but revised requirements in the new *ASI Connections Series* (References 41, 43) are now implemented. The old style flange doubler plates were butt-welded to the column web only but the new design model additionally requires fillet welds around the other edges of the doubler plates. Limcon assumes these to be 6 mm fillet welds for doubler plates up to 8 mm in thickness and 8 mm fillet welds otherwise.

Column flange doubler plates are not used with connections other than BMEP and HBEP connections.

RHS Bolted Moment End Plate (TMEP)

These connections are available for RHS (and SHS) *compact sections* only. The design models, based on 2-dimensional yield line analysis, were developed in a recent Sydney University research project that included full-scale testing. See References 27 and 28 for detailed information about the design models and the testing programme.

Bolts must be high-strength tensioned bolts, such as 8.8/TB or A325PT.

The design models are only valid for a compound butt/fillet weld of specified leg length all around the section. The fillet, which extends outside the face of the section by the leg dimension has an appreciable beneficial effect on the plate bending strength.

Axial Load Treatment

The tests on which the connection design model is based did not include axial forces – this is primarily a flexural model. Small axial forces are permitted by use of the procedure recommended in Ref. 18 to “convert the factored axial load into an equivalent moment that will be added to the factored connection moment for axial tension or subtracted from the factored connection moment for axial compression”. Limcon limits the axial load equivalent moment so that one flange remains in compression.

RHS Base Plates

Additional considerations are required if this connection is to be used to evaluate moment base plates for RHS columns:

- Some limit states relevant to base plates are not checked, e.g. concrete bearing failure.
- The TMEP model assumes high-strength tensioned bolts.
- For a thick plate the strength is determined by the bolts and the lever arm may be smaller than assumed in the TMEP model because the resultant compression could be inside the column flange.
- For a thin plate the strength is determined by the plate itself and the TMEP connection may be considerably stronger than a similar moment base plate (BASE) because of the two-dimensional yield line pattern and the presence of prying, which may not occur in base plates.

Thus, when the TMEP model is used to design a base plate it would be advisable to apply an additional strength reduction factor to account for the above effects. Calibrating the TMEP to a similar moment base plate (BASE) would be reasonable.

Hollow Structural Section Chord/Column Face Yielding

Truss chords and columns composed of hollow structural sections (HSS) need to be checked for face yielding, the development of a yield-line pattern where a plate or branch is welded to the chord or column. The face yielding strength is adversely affected by co-existing compressive stress in the chord or column and the formulae for face yielding strength contain an efficiency factor that is less than 1* when compressive stresses are present. In the CIDECT manuals and in Packer & Henderson (Ref. 25) this is f(n) for SHS/RHS and f(n') for CHS. ANSI/AISC 360 Chapter K uses the same values, referred to as the Q_f parameter.

The same method is used in Limcon for all connections in which face yielding is checked. These are the bracing connections (BRAC, KNG) and the HSS truss connections (TYT, TX, TKNG, TKNO). Single plate connections to an HSS column (WSP) should be checked for column face yielding if axial force is present in the beam. This check is not currently performed by Limcon but can easily be done by treating the single plate connection as a single brace connection, for which the necessary column compression and moment may be entered.

The items below are required for calculating face yielding efficiencies. See also, "Hollow Structural Section (HSS) Truss Connections" on p. 76.

N*op

When the chord is in compression on both sides of the joint N*op is the *smaller* compression force (not negative). If the chord on either side of the joint is in tension N*op is zero. It is required for checking face yielding in a CHS chord or column.

N*o

When the chord is in compression on both sides of the joint this is the *larger* compression force (not negative). If the chord is in compression on one side of the joint and in tension on the other, N*o is the compression force. It is required for checking face yielding in an SHS or RHS chord or column.

M*o

Bending moment in chord at joint due to transverse loading (not negative). It is required for checking face yielding in an HSS chord or column.

* Ref. 12 erroneously permits values of f(n) and f(n') exceeding 1.

Single Brace Connection (BRAC)

Limcon performs design checks on a simple isolated bracing cleat (gusset plate) connection as specified in Ref. 11 and additional checks in accordance with Ref. 12, including checks on HSS bracing members and attached plates. In addition to the connection types in Ref. 11 there are four concentric connections, two with cover (splice) plates and two with fork plates. All types are shown in the table below:

No.	Description	Attach. Plate	Cover Plates	Comp. Check
1	Single angle bolted on long leg			Ecc.
2	Single angle bolted on short leg			Ecc.
3	Double angles bolted on long legs			Conc.
4	Double angles bolted on short legs			Conc.
5	Tie rod welded to plate	Yes		n/a †
6	Flattened HSS bolted to gusset plate	Yes *		Ecc.
7	Slotted HSS bolted to gusset plate	Yes		Ecc.
8	HSS tee end bolted to gusset plate	Yes		Ecc.
9	I or C section, web bolted to gusset plate ×			Ecc.
10	I section with single plate bolted to web	Yes		Ecc.
11	I section with bolted web cover plates		Yes	Conc.
12	Slotted HSS with bolted cover plates	Yes	Yes	Conc.
13	I section with web plates & claw angles •		Yes	Conc.
14	Slotted HSS with bolted fork plates	Yes		Conc.
15	HSS tee end with bolted fork plates	Yes		Conc.
21	Single angle welded on long leg			Ecc.
22	Single angle welded on short leg			Ecc.
23	Double angles welded on long legs			Conc.
24	Double angles welded on short legs			Conc.
25	Slotted HSS welded to gusset plate			Conc.

* The flattened part of the HSS is checked as the attached plate.
× Flanges on one side of I section may be ground flush.
† The tie rod cannot be loaded in compression.
• Only available with maintenance.

Terminology

Limcon uses the following terms for the components of bracing connections:

Gusset plate – a rectangular plate to which the member or attached plate is connected. It is welded to the supporting member. Any corner intersected by a member is trimmed at right angles to the member axis.

Cleat or *simple cleat* – a gusset plate used for a single brace connection with its longitudinal sides parallel to the member axis.

Attached plate – a plate that is connected to the gusset plate and the member.

Cover plates – a pair of plates connecting a member or attached plate to a gusset plate.

HSS – any hollow structural section, CHS, SHS, or RHS. Some steel section libraries contain *pipe* sections – these are differentiated from round HSS (CHS) by their minimum specified yield strength of 35 ksi but are still classified as HSS by Limcon, using the correct Fy.

Rectangular Gusset Plate

By default, the cleat (gusset plate) for an inclined bracing member has sides parallel to the center-line of the bracing member. This arrangement simplifies the analysis of the cleat but the shape that is actually detailed may sometimes have one or two sides perpendicular to the support member, usually a column or truss chord.

There is an option button in the BRAC dialog box to change the simple cleat to a rectangular gusset plate (with a corner trimmed at right angles if it is intersected by the member). When this is done the connection is checked according to the conventional AISC method using the Whitmore section rather than the full width of the simple cleat. The weld to the supporting member is checked taking into account any moment applied by the gusset plate to the supporting member. The section through the gusset plate at the weld is also checked for yield under combined stresses using the interaction formula suggested by Astaneh-Asl (Ref. 29).

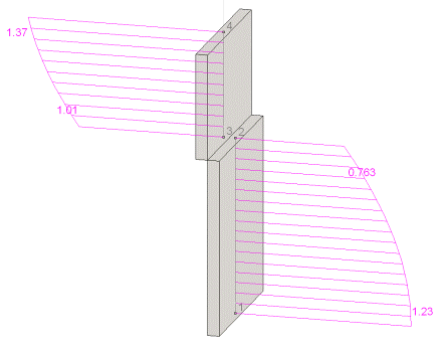
When the brace is in tension the rectangular gusset plate is checked for block shear using the same method as that used for a simple cleat. In addition, the rectangular gusset plate is checked for tearing to the edges, as shown in Ref. 25, p. 246.

Buckling Capacity

In computing the compression capacity of the bracing cleat connection determined by out-of-plane buckling of the plate or connected plates, Limcon takes compression and bending interaction into account rigorously according to the configured design code. Typical worked examples may be found in the AISC *Hollow Structural Sections Connections Manual* (Ref. 7). For ANSI/AISC 360 and CAN/CSA-S16 the k factor is 1.2 in accordance with Ref. 7, while for BS 5950, EC3, AS 4100, and NZS 3404 it is 1.0.

Unstiffened lapped plate connections (types 6, 7, and 8 in the above table) may be uneconomic as compression members. The compression capacity of similar concentric connections (types 12, 14, and 15 in the above table) is usually two or three times that of the eccentric connection. Bolts in the concentric connections work in double shear so it is often possible to use only one row of bolts, thereby making the connection shorter and stronger. Although the tee end with fork plates may be cheaper than the other concentric connections, it is not as strong in tension because of the non-uniform distribution of forces into the HSS walls.

In calculating the buckling capacity of an eccentric cleat it is necessary to determine the maximum moment acting on an equivalent column. The diagram below shows the bending moment resulting from a second-order analysis of a typical connection with lapped plates.



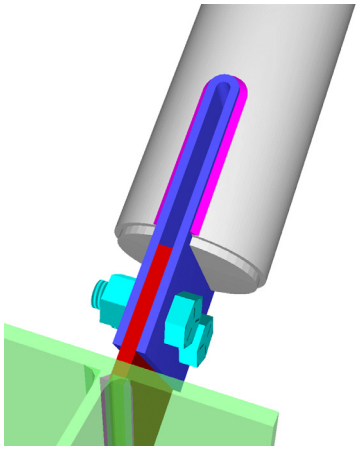
BENDING MOMENT IN CONNECTION WITH LAPPED PLATES

The bending moment is shared between the parts in the ratio of their stiffnesses. In this case, the eccentricity moment is shared almost equally between the gusset plate or cleat (lower) and the plate attached to the HSS member (upper). The moment is amplified about 50% by the p-delta effect. The amplified moment is used in the design code evaluation of the equivalent column.

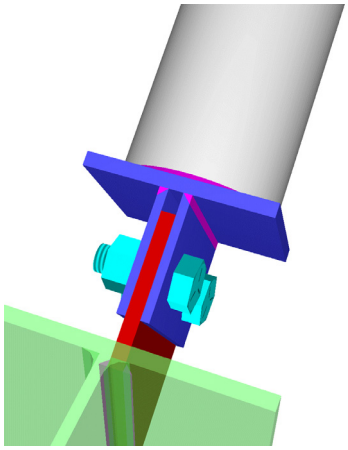
For lapped plate connections Limcon assumes that 50% of the eccentricity moment is applied to the gusset plate. For connections with a member connected directly to the gusset plate or cleat it is assumed that 10% of the eccentricity moment is applied to the cleat. Theoretically, it would be possible to calculate the distribution of the bending moment between the parts of the connection in each case but this would require additional data. Strength values predicted by Limcon agree well with published design examples (Ref. 7) and the results of recent (2009) full-scale testing conducted by Albermani et al. at the University of Queensland.

The type 9 connection with a channel brace may have a simple cleat bolted to the front of the section if it is no wider than the straight part of the web. Otherwise, the cleat or gusset plate must be on the back of the section, where the eccentricity will be greater and the compression strength less. In this case, the Limcon output shows the placement of the cleat that was assumed in computing the compression strength.

This connection type with an I section brace must have the flanges ground flush on the back of the section if a simple cleat is wider than the straight part of the web or if a rectangular gusset plate is used. Limcon assumes that the removal of the flanges does not affect the eccentricity and has no effect on the strength of the connection.



SLOTTED HSS WITH BOLTED FORK PLATES



HSS TEE END WITH BOLTED FORK PLATES

KT Gusset Plate Truss Connection (KTG)

This is a compound connection comprising a rectangular gusset plate welded to a support member with two or three bracing members connected to the gusset plate. It may be used for checking truss connections and also the chevron bracing connection. Limcon performs certain checks on the compound connection and then checks each component connection as a single brace connection with a rectangular gusset plate, using parameters determined by the KTG connection data. Any of the single brace connection types may be used for the component braces.

Without loss of generality Limcon shows each connection in a standard orientation. Brace 1 is shown on the left and brace 2 on the right. With two braces either brace angle may be 90º, making an N connection. If brace 3 exists it is the center brace.

Gusset plate yield and buckling are checked using the *Whitmore section*. The Whitmore pattern consists of two lines radiating at 30º from the center of each outer bolt in the first bolt row to the Whitmore section, along the center-line of the last bolt row (closest to the connection working point). This pattern is shown in the detail diagram for each component brace. The Whitmore equivalent column lengths, L1 (center), L2 (upper), and L3 (lower) are also plotted. Limcon automatically checks that none of the lines in the Whitmore pattern intersects an edge of the gusset plate.

The primary checks include:

- A check on the slenderness of gusset plate unsupported edges. The default value for the maximum permissible b/t ratio is 28 – a different value may be entered by clicking on the Gusset plate "**…**" button.
- Strength of the weld to the supporting member using the resultant of all brace forces.
- Yield of the gusset plate under combined stresses on a section adjacent to the weld.
- HSS chord face plastification and punching shear.

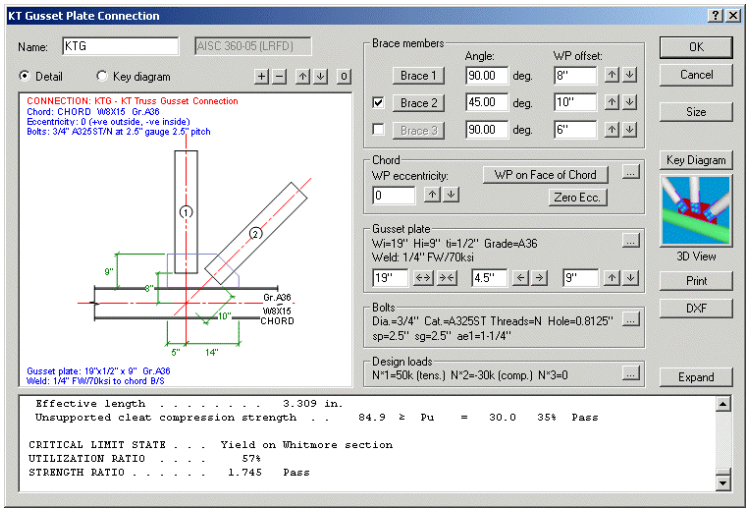
Secondary checks are performed for each component brace with the procedure used for a single brace connection. These include:

- Block shear and corner tearout (tension only).
- Bolt shear and bearing.
- Bolt tearing (tension only).
- Welds to member.
- Gusset plate buckling (concentric or eccentric).
- Shear lag.

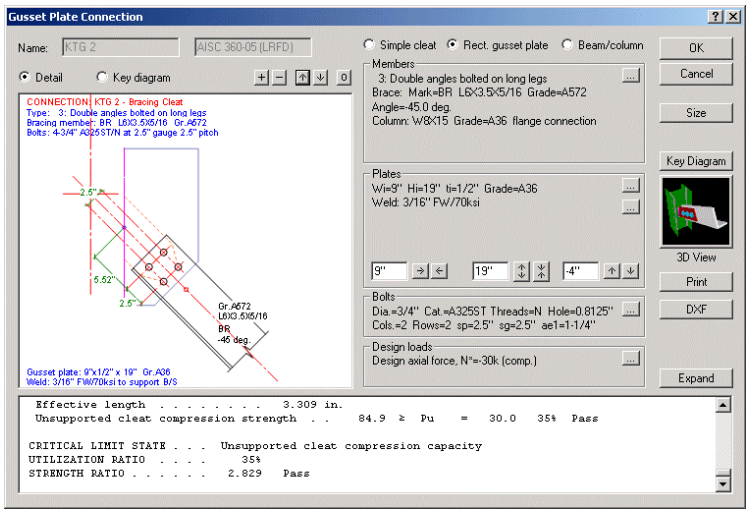
For gusset plate buckling the single brace effective length of the Whitmore equivalent column may be reduced if there is tension in an adjacent bracing member (see **Effective Lengths**, below).

Checks that are not relevant for the compound connection are omitted. These are:

- The check on the weld to the supporting member.
- The yield check on the section adjacent to the weld.
- HSS supporting member checks.



KTG DIALOG BOX



COMPONENT BRACE DIALOG BOX

Effective Lengths

While buckling in single brace connections is checked using an effective length factor (k) of 1.0 or 1.2, the value used for a beam/column brace is typically half of that. This recognizes the restraint provided by adjacent members and transverse tension in the gusset plate.

Limcon uses an effective length factor for each component brace connection that is determined as the single brace value (1.0 or 1.2, depending on design code) reduced by up to 50%, depending on the direction of any adjacent member and the tension force in it. If a member lies within 45º of the direction of the brace under consideration and it has a tension force of at least the same magnitude as the compression force in the brace under consideration, the effective length factor is reduced by 50%. As the angular displacement of the nearer tension member increases the effective length reduction diminishes linearly to zero when the angle is 90º. Similarly, effective length reduction diminishes linearly to zero as the force in the nearer tension member decreases to zero. Effective length reduction is achieved by multiplying the k factor by an *effective length modifier*.

Where an effective length modifier is used it is shown at the beginning of the output.

Noding Eccentricity

Where the working point does not coincide with the member center-line there is a *noding eccentricity* that causes a moment for which the chord must be designed. The face of an SHS or RHS chord is unable to resist significant moment so it is desirable to minimize the eccentricity for these sections.

Steps to Input and Check a KTG Connection

- When you create a new KTG connection a dialog box is displayed with the default connection. The sections, the gusset plate, other data, and the loads have to be changed as required.
- The KTG connection consists of a chord or column (shown in the horizontal position) and two or three braces (or branch members). The default connection has two braces – check the Brace 3 box if you want three. Brace 1 is always shown on the left, Brace 2 on the right, and if Brace 3 exists it is between them. In an "N" connection either Brace 1 or Brace 2 is vertical and Brace 3 does not exist.
- Most brace details are changed by clicking a brace button – this displays a subsidiary dialog box for the particular brace in which you can change the brace section, connection type, bolt or weld details, etc.
- With the "Set all" option selected, bolt details shown in the KTG dialog box take precedence over bolt details in subsidiary dialog boxes – e.g. when you change the bolt size in the KTG dialog box it is automatically set to the same size in all subsidiary dialog boxes.
- The output window at the bottom of the dialog box usually shows the end of the design check report. If the connection passes all design checks a utilization ratio not exceeding 100% will be shown.
- The output window contains only an error message if there is a fatal geometry error – e.g. if a brace does not overlap the gusset plate sufficiently. This type of error can usually be fixed by clicking

arrow buttons in the KTG dialog box to interactively resize or move the gusset plate, or adjust the offsets of the braces from the working point (WP).

- When you click a brace button the brace is shown in a subsidiary dialog box for a single brace connection (BRAC). In this dialog box the brace is shown rotated 90º clockwise. This is so because the brace is checked as a BRAC connection in which the "column" is the KTG chord. Some checks performed for a single brace are skipped because they are not relevant – e.g. the weld between the column (chord) and the gusset plate does not need to be checked here because it is checked in the KTG dialog box for the resultant of all brace forces.
- The lines of the Whitmore pattern are shown in the BRAC dialog box. A fatal error results if any of these intersects a free edge of the gusset plate. Similarly, if any bolt hole is too close to an edge of the gusset plate a fatal error results:
  `*** ERROR -- Gusset plate geometry error.`
  To fix this type of error you may interactively resize or relocate the gusset plate using the arrow buttons. When you click the OK button these changes will take effect in the KTG dialog box. You cannot change the gusset plate thickness in a subsidiary dialog box.

Note: In the standard version of Limcon, this connection type is only available with a current maintenance subscription.

Uniform Force Bracing Connection (UFBR)

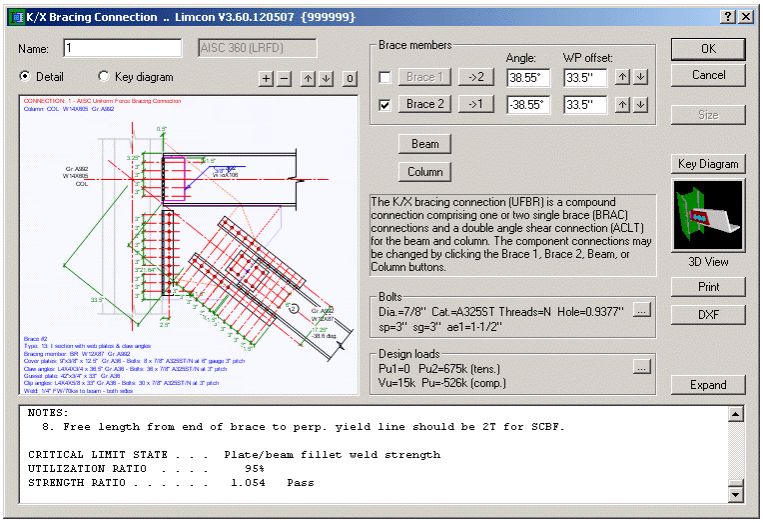
This is a compound connection comprising a beam to column connection (ACLT) and one or two bracing members (BRAC), each connected to a gusset plate that is welded to the beam and bolted to the column. Any of the single brace connection types may be used for the component braces. The upper brace is referred to as Brace1 while the lower brace is referred to as Brace 2.

The connection is evaluated using the uniform force method as described in the AISC *Steel Construction Manual* (Ref. 6). The essence of this method is that for each bracing connection the eccentricity must be negligibly small, so that there is no moment on the gusset/beam and gusset/column connections. The interactive "nudge" buttons in the Gusset Plate dialog box allow you to quickly adjust gusset plate dimensions to achieve the minimum eccentricity (see **The Adjust Gusset Plate Dialog Box,** below).

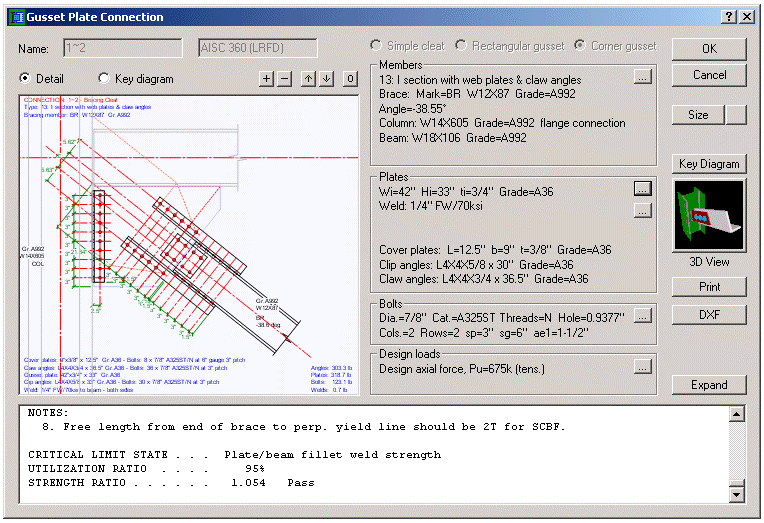
The beam/column connection is checked for the resultant shear and axial force. This is determined automatically from the input design actions, which are:

V* Beam shear.
N* Beam axial force (tension +ve).
N*1 Brace 1 axial force (tension +ve).
N*2 Brace 2 axial force (tension +ve).

Checks are also performed for each component brace, using the procedure for a single brace (corner) connection.



UFBR DIALOG BOX



COMPONENT BRACE DIALOG BOX

Steps to Input and Check a UFBR Connection

- When you create a new UFBR connection a dialog box is displayed with the default connection. The sections, the gusset plate, other data, and the loads have to be changed as required.
- The UFBR connection consists of a beam and column with a bracing member in the upper or lower quadrant, or both. A checkbox indicates whether each brace is present.
- Brace details are changed by clicking the brace button – this displays a subsidiary dialog box in which you can change the brace section, connection type, bolt or weld details, etc.
- With the “Set all” option selected, bolt details shown in the UFBR dialog box take precedence over bolt details in subsidiary dialog boxes – e.g. when you change the bolt size in the UFBR dialog box it is automatically set to the same size in all subsidiary dialog boxes.
- The output window at the bottom of the dialog box usually shows the end of the design check report. If the connection passes all design checks a utilization ratio not exceeding 100% will be shown.
- The output window contains only an error message if there is a fatal geometry error – e.g. if a brace does not overlap the gusset plate sufficiently. This type of error can often be fixed by clicking the arrow buttons in the UFBR dialog box to adjust the offsets of the braces from the working point (WP).
- When you click a brace button the brace is shown in a subsidiary dialog box for a single brace connection (BRAC).
- The lines of the Whitmore pattern are shown in the BRAC dialog box. A fatal error results if any of these intersects a free edge of the gusset plate. Similarly, if any bolt hole is too close to an edge of the

gusset plate a fatal error results:

```
*** ERROR -- Gusset plate geometry error.
```

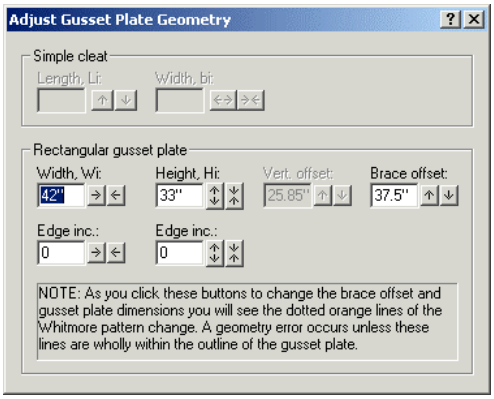
To fix this type of error you may interactively resize or relocate the gusset plate using the arrow buttons in the Plates dialog box (shown below). When you click the OK button in the subsidiary dialog box these changes will take effect in the UFBR dialog box.

The Adjust Gusset Plate Dialog Box

This dialog box is displayed when you click the top button in the Plates group box. It contains interactive "nudge" buttons that allow you to adjust each of the gusset plate dimensions until the eccentricity is minimized.

Limcon calculates and displays the eccentricity for each bracing connection. When this is zero, expression (13-1) in the AISC *Steel Construction Manual*, p.13-3 is satisfied. The warning exclamation mark is shown in the connection detail if the eccentricity exceeds 1" (25 mm). The process of minimizing the eccentricity involves the adjustment of the lengths of the horizontal (welded) and vertical (bolted) connections. These lengths are determined by the gusset plate dimensions shown in the dialog box; the width, height, and horizontal and vertical edge increments. A non-zero edge increment means that the corresponding free edge of the gusset plate is not parallel with the connected edge. It is often necessary to have one or both edge increments non-zero.

As you change the length of the column connection (vertical), the number of bolts is automatically adjusted. You may reduce the height of the connection until there are no bolts. This may be required for connections to a column web or when the elevation angle of the bracing member is small. In this configuration, the connection is categorized as Special Case 3 in the AISC *Steel Construction Manual*.


Adjust Gusset Plate Geometry
Simple cleat
Length, Li:
Width, bi:
Rectangular gusset plate
Width, Wi:
Height, Hi:
Vert. offset:
Brace offset:
42"
33"
25.85"
37.5"
Edge inc.:
Edge inc.:
0
0
NOTE: As you click these buttons to change the brace offset and gusset plate dimensions you will see the dotted orange lines of the Whitmore pattern change. A geometry error occurs unless these lines are wholly within the outline of the gusset plate.

GUSSET PLATE DIALOG BOX

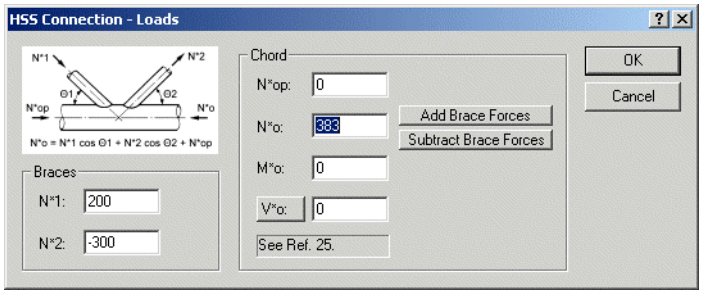
Note: In the standard version of Limcon, this connection type is only available with a current maintenance subscription.

Hollow Structural Section (HSS) Truss Connections

Three types of uniplanar HSS truss connection are available. These are the Y/T connection with one branch and the X and K/N connections with two branches. The K/N connection may be a *gap* connection or an *overlap* connection with different rules applying to each. The KT connection, with three branches, is not available in Limcon. Guidance is available from CIDECT (www.cidect.com) and Corus (www.corusgroup.com) on how to adapt K/N connection results for a KT connection.

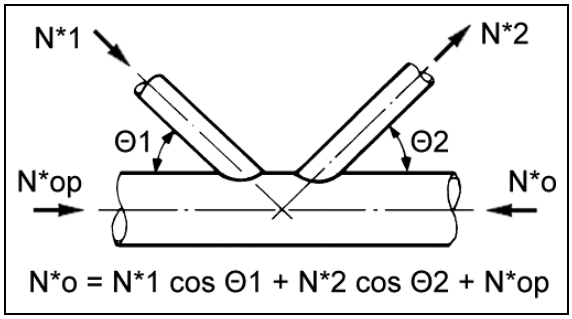
Without loss of generality Limcon shows each connection in a standard orientation. In K/N connections brace 1 is shown on the left and brace 2 on the right. Either brace angle may be 90º, making an N connection. In K/N overlap connections brace 2 is always the overlapped brace.

To enter the design loads for an HSS truss connection the dialog box shown below may be used when there is a single load case. For multiple cases load components are entered into a data grid, one line for each load case.



DIALOG BOX FOR ENTERING LOADS

The load components for a K/N gap connections are shown below.



DESIGN FORCES FOR K/N GAP CONNECTION

The load components are shown below. See “Hollow Structural Section Chord/Column Face Yielding” on p. 64 for more information.

N*op

The smaller chord compression force (not negative), zero if tension.

N*o

The larger chord compression force (not negative), zero if tension.

M*o

The bending moment in the chord at the joint due to transverse loading (not negative). Does not include moments caused by non-zero eccentricity, which may be ignored if connection geometric requirements are satisfied.

V*o

For K/N gap connections only, this is the shear force in the gap region of the chord (not negative).

N*1

N*1 is positive if tension and negative if compression. For K/N connections the brace forces must be of opposite sign. This value is also used for a section yield check.

N*2

N*2 is positive if tension and negative if compression. For K/N connections the brace forces must be of opposite sign. This value is also used for a section yield check.

Base Plate (BASE)

Pinned Base Plate

The pinned base plate is implemented according to Ref. 11 and *Design of Pinned Column Base Plates* – G. Ranzi & P. Kneen – ASI – Steel Construction Vol. 36 No. 2 – Sep. 2002 (Ref. 30). Note that References 11, 12, and 30 all contain formulae derived from yield-line patterns that may not be correct when bolts are outside the column profile. In all such cases Limcon evaluates alternative yield-line patterns to determine the minimum strength.

Moment Base Plate

The moment base plate is implemented according to AISC Steel Design Guide 1, *Base Plate and Anchor Rod Design – 2nd Edition* (Ref. 22). This does not discuss simultaneous bending about both axes. It is handled in Limcon by evaluating bending about each axis independently and then using an elliptical interaction equation for combining these effects.

The model assumes a single row of tension bolts outside the column flange but Limcon permits multiple bolt rows between the column flanges as well. Thus, the tension capacity computed by Limcon for multiple bolt rows in tension will be conservative. If bolt tension or plate yielding at the tension flange is critical a thinner plate may be justified by checking as a similar BMEP or MEPC. Note that there are two important caveats to be observed when using a moment end plate model to check a base plate:

- The base plate should be thick enough for thick plate behaviour to govern. Because of the limited bearing strength of the foundation full prying action cannot be assumed to occur, so the required strength must be attained without prying.
- The lever arm between centers of tension and compression may be significantly smaller for a base plate. In the moment end plate connection the center of compression is assumed to be at the compression flange while in a base plate it is determined by the distribution of stress in the concrete and may be well inside the compression flange.

Shear Analysis

Shear on a base plate may be resisted by friction if the column is in compression, by a shear key, and optionally by the anchor bolts. It is assumed that the shear is resisted firstly by the available base plate friction. If there is a shear key it resists the balance of the shear force up to the available strength of the shear key. When shear is permitted on the anchor bolts they are checked for the balance of the shear force. In moment base plates it is assumed that only half the total number of anchor bolts can participate in resisting shear.

Bolt Group (BGP)

The bolt group, which may contain up to 6 columns and 12 rows, permits the omission of any bolt on the 6×12 grid. This allows bolt groups with a staggered pattern to be checked, providing every bolt lies on a grid point. Limcon may be configured to use either the elastic method or the instantaneous center method for determining the capacity of a bolt group when it is subjected to an in-plane eccentric force or moment.

Elastic Method

The elastic method is the default method for determining bolt group capacity when Limcon is configured for BS 5950, EC3, AS 4100, or NZS 3404. It is simple and generally regarded as being conservative. In-plane loads are resolved into horizontal and vertical forces acting at the bolt group centroid and a co-existing moment. Centroidal forces are shared equally on all bolts and moment bolt forces are assumed to be proportional to the distance of the bolt from the centroid.

Instantaneous Center Method

The instantaneous center method is the default method for determining bolt group capacity when Limcon is configured for ANSI/AISC 360 or CAN/CSA-S16. It uses the "weak bolt / strong plate" model, in which the location of the instantaneous center (IC) is determined assuming that the force in each bolt is not affected by bearing or tearing failure. The bolt group strength ratio is comparable with the elastic method bolt shear strength ratio and is usually about 10% greater. The bolt group capacity should agree with any value determined from the tabulated coefficients in the AISC *Steel Construction Manual* (Ref. 6).

Joint rotation is computed at the strength limit state assuming that the ultimate deformation of the bolt furthest from the IC is 0.34".

Bolt Bearing and Tearing Checks

Limcon automatically checks bearing and tearing on every bolt in the group by determining the forces on each bolt at the design loading and comparing each of these with bearing and tearing capacities computed according to the design code. Bolts in the outside rows and columns are checked for external tearing where a force component is directed towards an edge. Internal tearing checks are performed on each bolt in the direction of the force components. If there is no bolt at the adjacent grid position in the direction of the tearing force the internal tearing check is omitted. Bolt forces for bearing/tearing checks are determined by the elastic method.

Slip Check

A slip check is performed for in-plane loading where a friction bolting category is specified. The slip check may be performed at service or factored loads. Bolt forces for the slip check are always determined using the elastic method.

Out of Plane Bending

Out-of-plane moments on bolt groups are always analysed using a plastic method in which all tension bolts are assumed to resist the ultimate bolt tension. Using the Ref. 6 method with the neutral axis at the bolt group centroid (also used in Ref. 34) there can be only one non-zero out-of-plane moment. Behaviour is not defined for biaxial out-of-plane bending.

Bolt Groups in Other Connections

Other connections, such as the bolted splice, web side plate, and angle cleat connections have bolt groups that may be subjected to moment and shear. These bolt groups are checked using the above procedures, the analysis method being determined by the configuration setting in effect.

Note: The critical bolt is identified by row and column in the output results for a bolt group analysis. Rows are numbered from top to bottom and columns from left to right.

Weld Group (WGP)

Several types of weld group may be analysed by the linear elastic method as set out in Ref. 11. The instantaneous center method is less appropriate for weld groups than bolt groups because of the directional variability of weld element ductility. The IC method is not available in Limcon for any weld group.

Alternative Analysis

The alternative analysis option is available for some types of weld group composed of elements at right angles. Usually, all weld elements in a weld group are assumed to participate but with this option selected direct shear is resisted only by elements aligned with the shear force direction (see AS 4100 Cl. 9.8.2.2).

Lower and Upper Bound Theorems

The Lower Bound Theorem

If a set of bending moments can be found which satisfies equilibrium throughout the structure and which does not violate the yield condition anywhere, then the corresponding load is either less than or equal to the correct collapse load.

(*Concrete Structures* – Warner, Rangan, Hall, Faulkes – 1998.)

This theorem has great significance for connection design. For a ductile material like steel, it means that any convenient distribution of stresses that satisfies equilibrium and does not cause yield gives a computed strength not exceeding the true strength (i.e. it is conservative). Many design checks are justified by this theorem, e.g. the assumption in simplified section analysis that moment is resisted exclusively by the flanges and shear by the web.

The Upper Bound Theorem

The external load which is calculated from any assumed collapse mechanism is either greater than or equal to the correct collapse load.

(*Concrete Structures* – Warner, Rangan, Hall, Faulkes – 1998.)

This theorem is the basis for the yield line methods that are used for checking moment end plates and base plates. It means that an unconservative solution is obtained for an unrealistic assumed yield line pattern. It is therefore very important that yield line mechanisms be verified by testing before they are used for design.

Seismic Checks

There are four seismic connections in Limcon:

1. Welded flange plate (WFP)
2. Bolted flange plate (BFP)
3. Bolted unstiffened extended end plate (MEPC 4E)
4. Bolted stiffened extended end plate (MEPC 4ES)

When the configured design code is ANSI/AISC 360-05 each of these connection types may be checked for any of the seismic structure types, OMF, IMF, and SMF. The seismic rules are found throughout:

- Ref. 13 – FEMA-350
- Ref. 14 – SEAOC Commentary on FEMA-350
- Ref. 15 – ANSI/AISC 358-05 – Seismic Provisions
- Ref. 16 – ANSI/AISC 341-05 – Prequalified Connections
- Ref. 17 – AISC Seismic Design Manual

For seismic connections Limcon presents additional calculations at the end of the standard (non-seismic) report. These calculations follow through the design procedure laid out in one of the above reference documents. The seismic checks can be quite stringent and you might find it difficult to make the connection "work". Seismic design is very interactive and not well suited to automatic sizing of the connection for compliance with all the rules.

Additional Checks

Connected Members

Limcon has insufficient information to perform comprehensive checks on the capacity of connected members. It is the designer's responsibility to check that specified design actions can be sustained by the connected members.

Design checks are shown for the member where the connection design model includes them (e.g. WSP). In some connections section capacities are shown so that the design loads may be seen in context. This does not imply that the connection is safe for the section capacity. In hollow section connections, for example, the shear capacity in the connection may be substantially less than the theoretical section shear capacity because of the possibility of local buckling at the connection location.

Other Limit States

All limit states checked by Limcon are reported. It is the responsibility of the designer to consider whether there are other limit states that should also be checked.

Range Check on Input Values

Limcon checks many input parameters and displays a warning or error message when a parameter is outside a certain range of values. In some cases, it may be possible to enter untested or unusual values for a parameter. The designer should use engineering judgment to decide whether the input data is reasonable.

Welds

Specifying weld details is always the responsibility of the designer. Information concerning welds in Limcon output and details may not be sufficiently thorough for specification purposes.

Output References

A reference is shown in the rightmost column for many of the limit states reported in the Limcon output. It is usually a reference to a clause of the configured design code but there are also references to the notes in the table below.

Note 1	Flexural yield capacity ignoring section slenderness.
Note 2	Shear yield capacity ignoring slenderness.
Note 3	Tensile yield capacity of section.
Note 4	Compression yield capacity of section ignoring slenderness.
Note 5	Eccentricity moment shared 50% gusset plate, 50% attached plate.
Note 6	Eccentricity moment shared 90% gusset plate, 10% bracing member.
Note 7	Empirical factor representing increased buckling strength due to cover plates. Only permitted for two or more rows of tensioned bolts and effective length factor less than 1. It is the responsibility of the designer to determine whether this allowance is appropriate in the particular circumstances.
Note 8	Free length from end of brace to perpendicular yield line should be 2T for SCBF.
Note 9	Design code does not give shear lag factor for 1 bolt row.
Note 10	Shear capacity reduced by 20% with grout pad - see AISC SDG 1 p.29.
Note 11	Using elliptical interaction equation for combined shear and tension.
Note 12	
Note 13	
Note 14	
Note 15	
Note 16	
Note 17	
Note 18	
Note 19	
Note 20	

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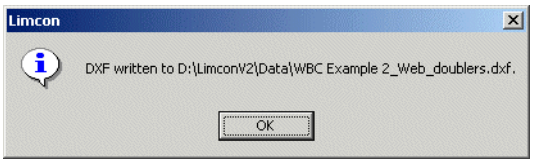
5:DXF Output

General

Clicking on the DXF button in a connection dialog box outputs the connection detail to an AutoCAD-compatible DXF (Release 12). The detail is similar to the diagram of the connection displayed in the connection dialog box. Each time the DXF button is clicked a new DXF is created with a name of the form “Job name_connid.dxf”, where “Job name” is the job name and “connid” is the connection name input by the user (up to 20 characters). The DXF is saved to the data folder and a message box shows the path and name of the file written.



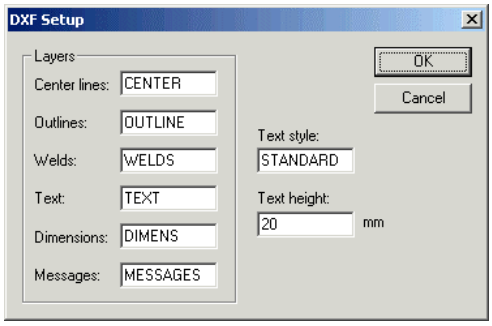
Any existing DXF for a particular connection will be overwritten the next time the DXF button is clicked while editing that connection.

The Header DXF

Drafting variables such as line types and dimension style are specified in the header DXF. This is a file called Limcon.dxf that is located in the Limcon library folder, normally \Limcon\Lib. The header DXF is, in effect, a prototype drawing to which the connection detail is added. It is read by Limcon, interpreted as required, and written to the output DXF. The Limcon.dxf file distributed with Limcon is compatible with AutoCAD Release 12. When the special version, Limcon_US.dxf, is available DXF units will be inches when US customary units are selected. It may be changed as required by editing with a text editor, such as MsEdit. Items that may be changed include layer names, colors, line types, and the dimensioning variables. *To avoid the possibility of conflicts between the prototype drawing and the header DXF, it is recommended that your CAD program is configured for no prototype drawing.*

DXF Setup

You may select the **File > Configure > DXF** command to determine the layers for the various components of the drawing. The dialog box below shows the default layer names, each of which already appears in the header DXF (layer "0" is also included). Adding a new layer name necessitates the addition of a block of data for that layer in the header DXF.



FILE > CONFIGURE > DXF

The text style must also be included in the header DXF. The text height and dimension text height is determined by the value in the dialog box.

6:Editing the Section Library

General

Limcon refers to the current steel section library for information required for checking, and design of steel connections. The **File > Configure > Section Library** command allows you to select any available library as the current library. Using the method described below you may edit the library. Special section libraries may also be created.

Section Library

Limcon library files have the file name extension “lib” (e.g. Asw.lib, Uk2000.lib) and cannot be listed, printed, or edited. For each library file there is a corresponding source file, an ordinary text file having a file name extension “asc”. Library source files may be manipulated by the Section Library Manager.

Section Name

Each section has a unique section name with up to 15 characters. Blanks are not permitted. The section name must have one contiguous alphabetic group between 1 and 4 characters long. This is the *section mnemonic*.

Section Mnemonic

The section mnemonic is used in Limcon for identifying the section type. It is embedded in the section name and, apart from “X”, is the only part of the name that may be alphabetic. An “X” character contiguous with the section mnemonic is part of the section mnemonic. Apart from the section mnemonic, “X” characters with numeric characters before and after may be included in the section name.

Examples of valid section names are, “200UB25.4”, “88.9X2.6CHS”, “CTT380X100”, “100XX”, “XX100”, and “W14x311”. Invalid names include “200UB25.4H1” (two separate alphabetic groups), “CTT380X100X” (trailing X), “X200UB25.4” (leading X), and “XXBOX100” (mnemonic exceeds 4 characters).

When adding new sections to a library you may choose any suitable section mnemonic. A single character “E”, however, may not be used as

a section mnemonic because the section name would then be confused as a number in exponential format.

Section Categories

Each group of sections in the library is assigned a *section category*. Every section in a section category should have the same section mnemonic. The section category number is shown in the library source file under the heading SC. When choosing a section, you first choose the section category and Limcon then displays all the sections in the category. All sections within a category must have the same design type and section mnemonic.

Design Type

For design purposes each section is classified according to its *design type*. The design type number is shown in the library source file under the heading DT. The design type is used to interpret the section properties and it determines the applicable design code rules. The table below lists valid design types, together with some of the common section mnemonic codes for these types.

DT	Mnemonic	Section Type
1	TFB	Taper flange beam
2	UB, WB	Universal beam or welded beam
3	UC, WC	Universal column or welded column
4	RHS	Rectangular hollow section
5	SHS	Square hollow section
6	CHS	Circular hollow section
7	PFC	Parallel flange channel
8	BT, CT	Tee section
9	EA	Equal angle
10	UA	Unequal angle
11	DAL	Double angles, long legs together
12	DAS	Double angles, short legs together
16	STA	Starred angles
22	QAN	Quad angles
13	UBP	Universal bearing pile
17	TFC	Taper flange channel
18	ROD	Round
19	BAR	Rectangular bar
20	CTT	Double channels, toes together
21	CBB	Double channels, back-to-back
24	CA	DuraGal cold-formed angle
25	CC	DuraGal cold-formed channel

30	-	Section with analysis properties only
33	UI	Unsymmetrical I section
34	BOX	Box section
35	C	Lipped cee
36	Z	Lipped zed

Steel Grades

Limcon determines yield and ultimate tensile stresses from recognized steel grades. Up to three grades, G1, G2, and G3, may be included for each section. If there is only one grade available for a section, enter it as G1 and enter zero for G2 and G3. If there are two grades available, G3 must be zero.

Residual Stress Code

Limcon distinguishes welded sections from rolled sections by the residual stress code ("f" in the table below).

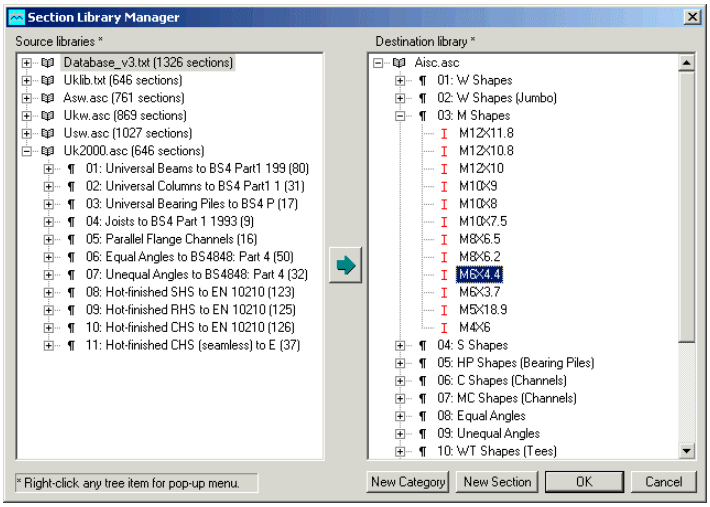
f	Section Type
1	Stress relieved
2	Hot-rolled
3	Cold-formed
4	Lightly welded
5	Heavily welded

Section Library Manager

Library source files may be manipulated by the Section Library Manager.

You may edit any library source file supplied but it is preferable to make a copy and edit that – otherwise, you will lose your changes when you next update library files.

After you have selected the destination library, either an existing library source file or a new one, the dialog box below is displayed. A tree view of the destination library, empty if new, is shown on the right while all available library source files are shown on the left. Each library may be expanded to show the section categories and each of these may be expanded to show the sections contained in the category.

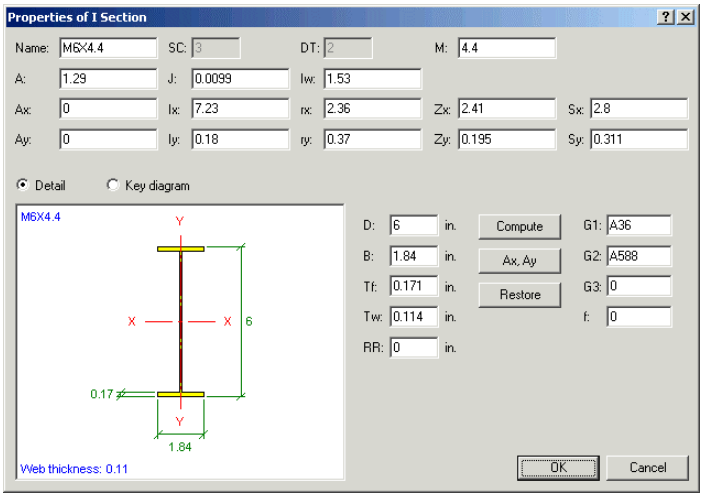


SECTION LIBRARY MANAGER

You may select any library, category, or section on the left and click the arrow button to send it to the destination library on the right. Double-clicking a section on the right will display a dialog box in which you may alter any value.

Section Properties Dialog Box

The properties of any section in the destination library may be displayed by right-clicking the section and choosing Section Properties on the pop-up menu. Double-clicking the section will also display the section properties dialog box. The dialog box shows all the values stored in the library for the section. Any values that are not disabled in the dialog box may be changed. Click the ? button at the top and then click on any item for help. Clicking the **Compute** button computes all derived values from the current dimensions. The **Restore** button sets all edit boxes back to their original values.



SECTION PROPERTIES DIALOG BOX FOR I SECTION

The G1, G2, and G3 boxes show the grades in which the section is available. Only grades recognized by Limcon should be used – see "Steel Grades" on p. 39. No more than three grades are permitted and unspecified grades must be zero. If one grade is specified it must be G1 and if two are specified they must be G1 and G2.

Section property dialog boxes for some sections have an **Ax, Ay** button, which computes shear areas. Shear areas are not used by Limcon.

Compiling a Library

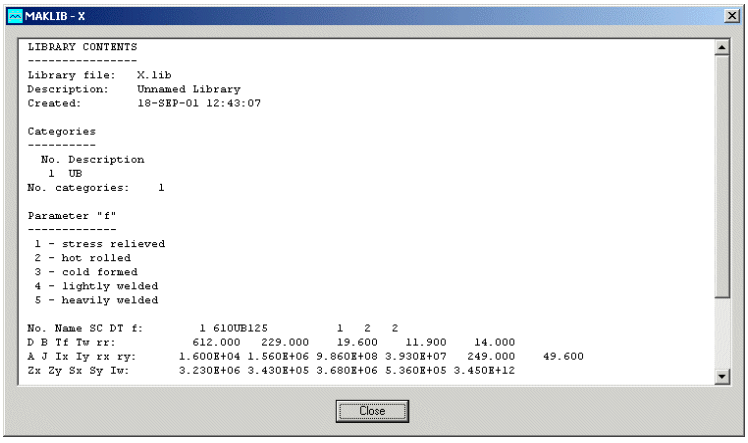
When you click the Save button Limcon offers to compile the new library file. Click Yes in the dialog box below to do this.

COMPILING THE LIBRARY

The library compiler reads and interprets the library source file and writes a Limcon library file. The value of any section property value input as zero is computed automatically provided sufficient dimensions for the calculation have been input. When compilation has finished successfully a report is displayed, as shown below. This report lists any errors or inconsistencies detected in the input data. The library report for the current library may be displayed from the Limcon **File > Configure** menu.

All section property values are computed from the section dimensions and where the corresponding input value differs by more than 1%, a warning message results. Section properties are computed only approximately for some taper flange sections and warnings for these sections may not be valid.

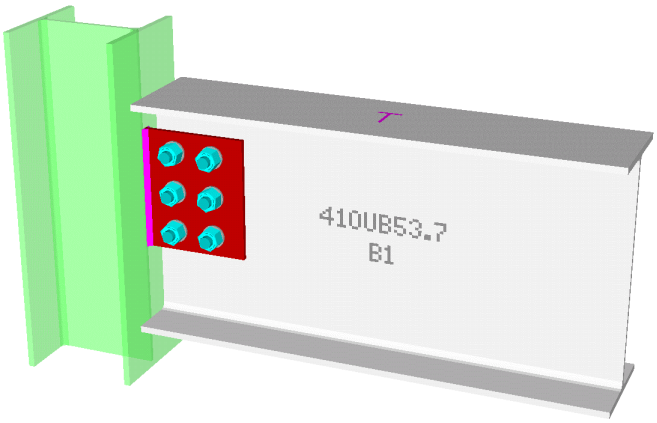
Note: Microstran and Limcon libraries are compatible.


MAKLIB - X
LIBRARY CONTENTS
Library file: X.lib
Description: Unnamed Library
Created: 18-SEP-01 12:43:07
Categories
No. Description
1 UB
No. categories: 1
Parameter "f"
1 - stress relieved
2 - hot rolled
3 - cold formed
4 - lightly welded
5 - heavily welded
No. Name SC DT f: 1 610UB125 1 2 2
D B Tf Tw rr: 612.000 229.000 19.600 11.900 14.000
A J Ix Iy rx ry: 1.600E+04 1.560E+06 9.860E+08 3.930E+07 249.000 49.600
Zx Zy Sx Sy Iw: 3.230E+06 3.430E+05 3.680E+06 5.360E+05 3.450E+12
Close

COMPILING THE LIBRARY – REPORT

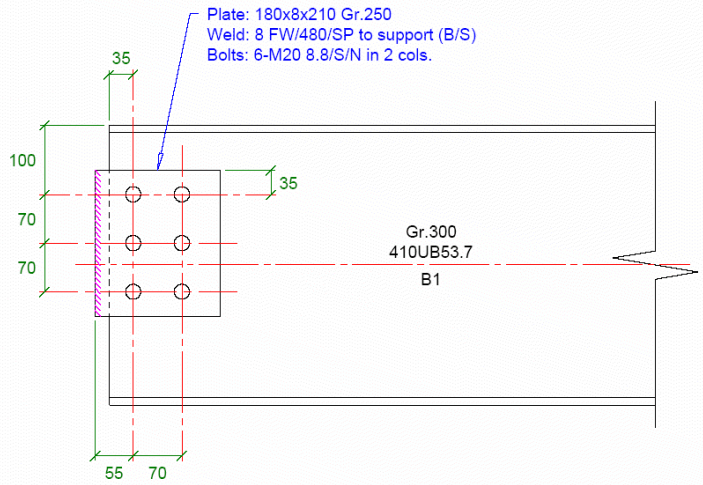
7:Examples

Web Side Plate / Single Plate / Fin Plate Connection



This is the design example from p. 76 of *Design of Structural Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box. Many different styles of printout may be obtained by adjusting parameters in the Page Setup dialog box (**File > Page Setup** command).

CONNECTION: WSP - Web Side Plate




```
LIMCON V3.5                                                    29-JUN-07
                                                               15:10:02

 Connection: WSP
       Type: Web Side Plate
    Country: Australia
      Units: Metric
Design code: AS 4100 (ASI 2007)

Beam:  Mark=B1  Section=410UB53.7   Grade=300   Span= 8000 mm
     D =   403 mm    Root rad. =   11.4 mm    fyf =  320 MPa
     B =   178 mm          Area = 6.8900E+03   fyw =  320 MPa
    Tf =  10.9 mm            Sx = 1.0600E+06    fu =  440 MPa
    Tw =   7.6 mm

Cope dimensions   Top:  Not coped
                  Bottom:  Not coped

Plate:
 210x180x8  Gr./fy/fu=250/280/410 MPa

Bolts:
 6-M20 8.8/S/N in 2 cols. at 70 pitch.
 Support to 1st column 55 , horizontal spacing between columns 70 .

Weld:
 8 FW fu=480 MPa/SP to support.

Support:  Mark=C1  Section=200UC46.2   Grade=300
     D =   203 mm    Root rad. =   11.4 mm    fyf =  300 MPa
     B =   203 mm          Area = 5.9000E+03   fyw =  320 MPa
    Tf =  11.0 mm            Sx = 5.0000E+05    fu =  440 MPa
    Tw =   7.3 mm
 Connection to column flange.

 MINIMUM SHEAR FORCE CHECK
```

Input design actions are not automatically increased if they are less than the specified minimum actions. Minimum actions may be set in any load case. This check warns if the shear force is less than the specified minimum (40 kN) for all load cases.
* Shear force exceeds specified minimum in at least one load case.

INPUT DESIGN ACTIONS
Shear, V* . . . . . 180.0 kN
Axial, N* . . . . . 0.0 kN

Using ASI 2007 model...

Eccentricity . . . . . 90.0 mm
Eccentricity moment, M* . . . . . 16.2 kN.m

GEOMETRY CHECKS...
CHECK 1 - Detailing:
Ref. 35: Steel Connections Design Guide 5 - Web Side Plate Connection
Australian Steel Institute - 2007

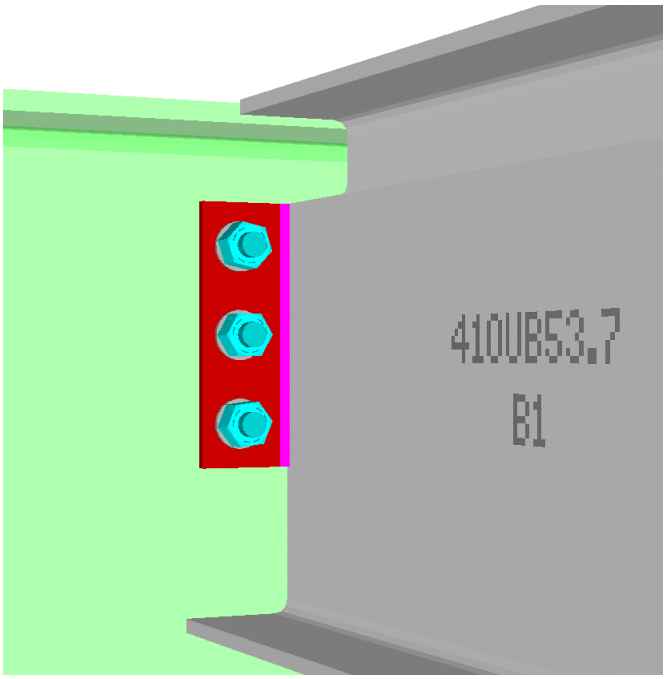
Plate fillet weld size	8.0	>=	6.0		Pass
	8.0	<=	8.0		Pass
Bolt diameter	20.0	>=	20.0		Pass
	20.0	<=	24.0		Pass
Bolt ultimate stress	830	>=	830		Pass
No. bolt rows	3	>=	2		Pass
	3	<=	9		Pass
Bolt spacing, sp	70.0	>=	50.0		Pass
	70.0	<=	90.0		Pass
Bolt gauge, sg2	70.0	>=	50.0		Pass
	70.0	<=	90.0		Pass
Plate unsupported length	55.0	<=	56.0		Pass
Plate fy	280	>=	250		Pass
	280	<=	320		Pass
Plate thickness	8.0	>=	6.0		Pass
	8.0	<=	10.0		Pass
Plate depth	210.0	>=	201.5		Pass
Plate vertical edge distance	35.0	>=	30.0		Pass
Plate horizontal edge distance	55.0	>=	30.0		Pass
Clearance to support	20.0	>=	20.0		Pass
Beam fy	320	>=	280		Pass
	320	<=	320		Pass
Web thickness	7.6	<=	10.0		Pass
Web horizontal edge distance	35.0	>=	30.0		Pass

DESIGN CAPACITY CHECKS...

					Capacity ratio --------+			
					Design action --+			
				+-- Design capacity				
				|				
CHECK 2 - Weld:								
Weld length (each side)	210 mm							
Design moment	16.2 kN.m							
Weld capacity	198.4	>	V*	=	180.0	1.10	Pass	
CHECK 3 - Bolts:								
Plate:								
Bolt shear (critical bolt row, column)...								
Bolt shear . . . . . (1,2)	92.6	>	V*res	=	66.1	1.40	Pass	
Bolt bearing/tearing (critical bolt row, column)...								
Bolt bearing . . . . . (1,2)	188.9	>	V*res	=	66.1	2.86	Pass	
Bolt group ext. tearing (btm.) . . . (3,2)	100.4	>	V*v	=	51.0	1.97	Pass	
Bolt group ext. tearing (right) . . (1,2)	159.4	>	V*h	=	42.1	3.79	Pass	
Bolt group int. tearing (vert.) . . (1,2)	171.2	>	V*v	=	51.0	3.35	Pass	
Bolt group int. tearing (horiz.) . . (1,1)	171.2	>	V*h	=	42.1	4.07	Pass	
Web:								
Bolt bearing/tearing (critical bolt row, column)...								
Bolt bearing . . . . . (1,2)	192.6	>	V*res	=	66.1	2.91	Pass	
Bolt group ext. tearing (left) . . . (1,1)	102.3	>	V*h	=	42.1	2.43	Pass	
Bolt group int. tearing (vert.) . . (2,2)	174.6	>	V*v	=	51.0	3.42	Pass	
Bolt group int. tearing (horiz.) . . (1,2)	174.6	>	V*h	=	42.1	4.15	Pass	
CHECK 4 - Plate:								
Shear yield capacity	211.7	>	V*	=	180.0	1.18	Pass	AS4100 5.11.3
Shear rupture capacity	255.1	>	V*	=	180.0	1.42	Pass	
Plate moment capacity	247.0	>	V*	=	180.0	1.37	Pass	
Plate block shear capacity	402.7	>	V*	=	180.0	2.24	Pass	

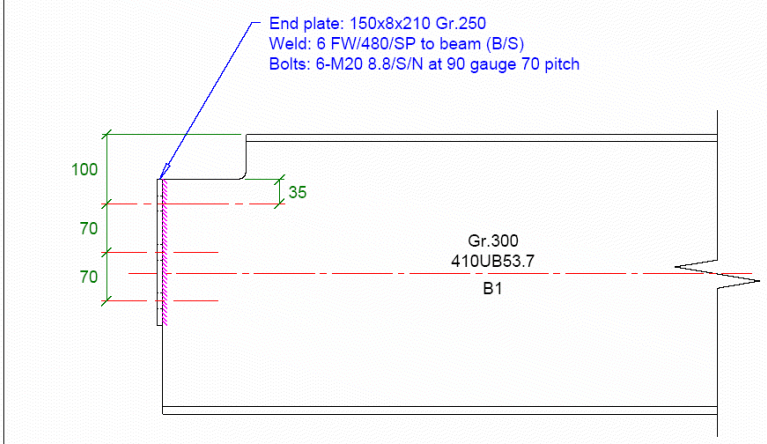
```
CHECK 5 - Beam Shear:
 Shear capacity (non-slender web)  . . . . .   529.3  >  V*    =  180.0  2.94  Pass

CHECK 6 - Beam Block Shear:
 Beam not coped - check not necessary.

CHECK 7 - Coped Beam Bending:
 Beam not coped - check not necessary.

CHECK 8 - Beam Rotation:
 Rotation for UDL (rad.) . . . . . .   0.026  <=   0.020              FAIL  Informative
 Rotation for contact (rad.) . . .   0.086
 Contact rotation capacity . . . . . .   605.2  >  V*    =  180.0  3.36  Pass
 Max. bolt shear deformation . . . . . .     2.0  <=     5.0              Pass

CHECK 9 - Coped Beam Buckling:
 Beam not coped - check not necessary.

CHECK 10 - Support Member:
 Supporting column flange - check not necessary.

CRITICAL LIMIT STATE . . .  Weld capacity
UTILIZATION RATIO  . . . .     91%
CAPACITY RATIO, ø.Ru/S* .    1.102   Pass
```

Flexible End Plate Connection



This is the design example from p. 58 of *Design of Structural Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

CONNECTION: FEP - Flexible End Plate



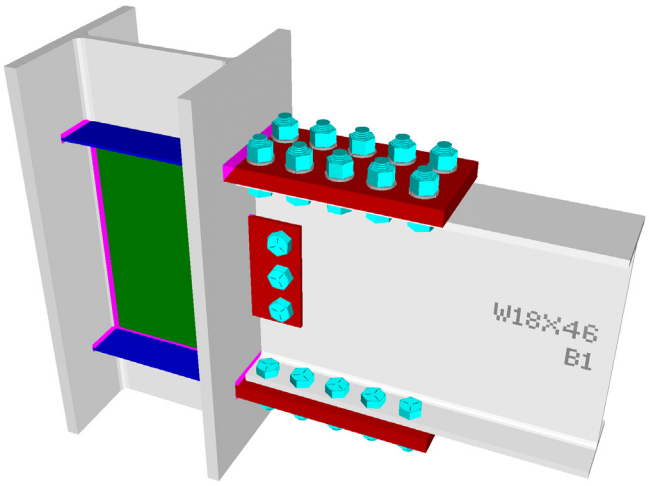
Top cope = 65x120

```
LIMCON V3.5                                                    29-JUN-07
                                                               15:12:03
 Connection: FEP
       Type: Flexible End Plate
    Country: Australia
      Units: Metric
Design code: AS 4100 (ASI 2007)

Beam:  Mark=B1  Section=410UB53.7   Grade=300   Span= 8000 mm
     D =   403 mm     Root rad. =   11.4 mm     fyf =  320 MPa
     B =   178 mm          Area = 6.8900E+03    fyw =  320 MPa
    Tf =  10.9 mm            Sx = 1.0600E+06     fu =  440 MPa
    Tw =   7.6 mm

Cope dimensions   Top:  Depth = 65      Length = 120
                  Bottom:  Not coped

Support:  Mark=C1  Section=610UB101   Grade=300
     D =   602 mm     Root rad. =   14.0 mm     fyf =  300 MPa
     B =   228 mm          Area = 1.3000E+04    fyw =  320 MPa
    Tf =  14.8 mm            Sx = 2.9000E+06     fu =  440 MPa
    Tw =  10.6 mm
 Connection to beam web.

End plate:
 210x150x8  Gr./fy/fu=250/280/410 MPa
 Weld 6 FW fu=480 MPa/SP to web of beam.
 Bolts 6-M20 8.8/S/N in 3 rows at 70 pitch and 90 gauge.

MINIMUM SHEAR FORCE CHECK
 Input design actions are not automatically increased if they are less than the specified
 minimum actions. Minimum actions may be set in any load case. This check warns if the
 shear force is less than the specified minimum (40 kN) for all load cases.
 * Shear force exceeds specified minimum in at least one load case.
```

```
INPUT DESIGN ACTIONS
 Shear, V* . . . . . .   200.0 kN
 Axial, N* . . . . . .     0.0 kN

Using ASI 2007 model...

GEOMETRY CHECKS...
CHECK 1 - Detailing:
 Ref. 36: Steel Connections Design Guide 6 - Flexible End Plate Connection
          Australian Steel Institute - 2007
 Plate fillet weld size  . . . . . .     6.0  >=     6.0              Pass
                                         6.0  <=     8.0              Pass
 Bolt diameter . . . . . .              20.0  >=    20.0              Pass
                                        20.0  <=    24.0              Pass
 Bolt ultimate stress  . . . . . .      830   >=    830               Pass
 No. bolt rows . . . . . .                3  <=      9               Pass
 Bolt gauge, sg  . . . . . .             90.0  >=    72.0              Pass
                                         90.0  <=   112.0              Pass
 Plate fy  . . . . . .                  280   >=    250               Pass
                                        280   <=    320               Pass
 Plate thickness . . . . . .             8.0  >=     8.0              Pass
                                         8.0  <=    10.0              Pass
 Plate depth . . . . . .                210.0  >=   201.5              Pass
 Plate vertical edge distance  . . . .   35.0  >=    30.0              Pass
 Plate horizontal edge distance  . . .   30.0  >=    30.0              Pass
 Beam fy . . . . . .                    320   >=    280               Pass
                                        320   <=    400               Pass

DESIGN CAPACITY CHECKS...
                                            Capacity ratio --------+
                                            Design action --+      |
                                          +-- Design capacity |    |
                                          |                   |    |
CHECK 2 - Weld:
 Weld length (each side) . . . . .   210 mm
 Weld shear capacity . . . . . .    410.6  >  V*    =  200.0  2.05  Pass

CHECK 3 - Bolts:
 Bolt shear capacity . . . . . .    555.8  >  V*    =  200.0  2.78  Pass
 Plate ply bearing capacity  . . . .1133.6  >  V*    =  200.0  5.67  Pass
 Plate ply tearing capacity  . . . .602.2  >  V*    =  200.0  3.01  Pass

CHECK 4 - Plate:
 End plate shear capacity  . . . . .    423.4  >  V*    =  200.0  2.12  Pass
 Plate block shear capacity  . . . .    446.3  >  V*    =  200.0  2.23  Pass

CHECK 5 - Beam Web at End Plate:
 Beam web shear capacity at end plate  . . .   275.8  >  V*    =  200.0  1.38  Pass

CHECK 6 - Beam Shear:
 Coped web shear capacity  . . . . .    387.3  >  V*    =  200.0  1.94  Pass

CHECK 7 - Coped Beam Bending:
 Section bending capacity  . . . . .     97.2 kN.m
 Coped web moment capacity . . . . .    759.6  >  V*    =  200.0  3.80  Pass
  Estimated max. cope length . . .    400 mm

CHECK 8 - Beam Rotation:
 Rotation for UDL (rad.) . . . . .   0.028
 Rotation for contact (rad.) . . .   0.063
 Contact rotation capacity . . . . . .   440.6  >  V*    =  200.0  2.20  Pass

CHECK 9 - Coped Beam Buckling:
 NOTE: Coped beam must be restrained against lateral torsional buckling.
 Top cope depth  . . . . . .     65.0  <=   201.5              Pass
 Web yield stress, fyw . . . . . .   320 MPa
 Web slenderness, tw/d . . . . . .    53.0
 Max. tw/d for cope length = D . .    50.4
 Max. cope length  . . . . . .    345 mm
 Top cope length . . . . . .    120.0  <=   344.7              Pass
  As above geometric requirements are satisfied, the coped web does not
  have to be checked for buckling.
 Buckling check to AISC SCM 13th p.9-7 (Cheng, Yura, Johnston)...
  Critical stress, Fcr . . . . . .   661 MPa
  Critical stress, Fcr <= Fy . . .   320 MPa
```

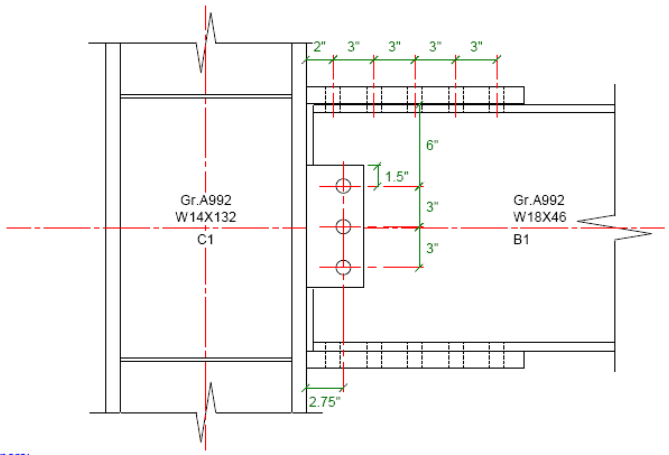
```
   Single coped web buckling capacity . . . .   503.3  >  V*    =  200.0  2.52  Pass  Informative
   Estimated max. cope length . . .    310 mm

 CHECK 10 - Support Member:
  Support beam local shear capacity . . . . .  2205.3  >  V*    =  200.0  11.0  Pass
  Shear capacity - beam both sides  . . . . .  2205.3  >  2V*   =  400.0  5.51  Pass  Informative
  Support beam web bearing capacity . . . . .  1611.9  >  V*    =  200.0  8.06  Pass
  Bearing capacity - beam both sides  . . . .  1611.9  >  2V*   =  400.0  4.03  Pass  Informative
  Support beam web tearing capacity . . . . .  1460.8  >  V*    =  200.0  7.30  Pass
  Tearing capacity - beam both sides  . . . .  1460.8  >  2V*   =  400.0  3.65  Pass  Informative

 CRITICAL LIMIT STATE . . .  Beam web shear capacity at end plate
 UTILIZATION RATIO  . . . .     73%
 CAPACITY RATIO, ø.Ru/S* .    1.379   Pass
```

Bolted Flange Plate Connection



This example illustrates the additional design checks carried out for seismic connections. Seismic design capability is enabled only when the design code is ANSI/AISC 360.

CONNECTION: BFP_3 - Flange Plate Connection
Flange plates: 7.75"x1-1/4"x16" Gr.US50
Top flange plate weld: CJPGW/70ksi to col.
Btm. flange plate weld: 1/4" FW/70ksi to col.
Bolts: 10-1" A490PT/X in 2 cols. at 4" gauge



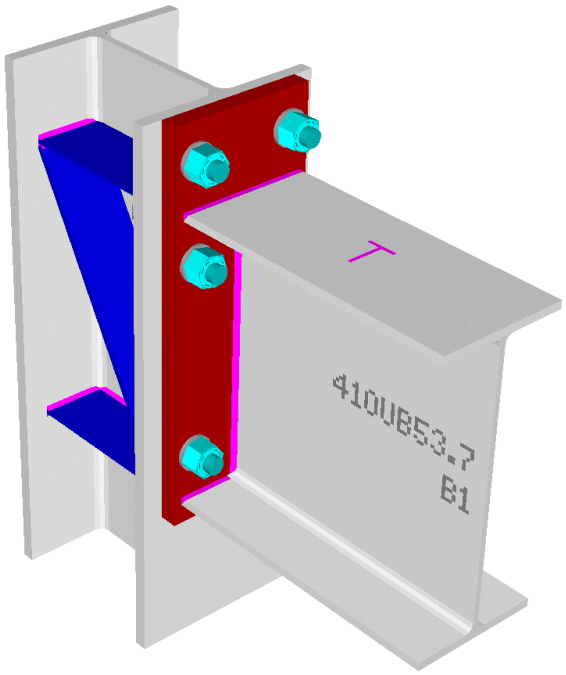
Stiffeners:
Top: 3.5"x1/4"x12.64" Gr.A36 - Weld=1/4" FW/70ksi Side=none End=full
Web doubler one side: 11.4567"x5/16"x18.622" Gr.A36 CJPGW all around
Btm.: 3.5"x1/4"x12.64" Gr.A36 - Weld=1/4" FW/70ksi Side=full End=full

```
LIMCON V3.5                                                    31-OCT-06
                                                                23:27:21

 Connection: BFP_3
       Type: Flange Plate Connection
             3: All bolted
             Special Moment Frame (SMF)
    Country: US
      Units: US customary
Design code: ANSI/AISC 360-05 (LRFD)

Beam:  Mark=B1  Section=W18X46   Grade=A992   Span= 360 in.
     D = 18.10 in.   Root rad. =   0.41 in.   fyf = 50.0 ksi
     B =  6.06 in.        Area = 1.3500E+01   fyw = 50.0 ksi
    Tf =  0.61 in.          Zx = 9.0700E+01    fu = 65.0 ksi
    Tw =  0.36 in.

Column:  Mark=C1  Section=W14X132   Grade=A992
     D = 14.70 in.   Root rad. =   0.60 in.   fyf = 50.0 ksi
     B = 14.70 in.        Area = 3.8800E+01   fyw = 50.0 ksi
    Tf =  1.03 in.          Zx = 2.3400E+02    fu = 65.0 ksi
    Tw =  0.64 in.

Shear plate:
 9"x4.25"x0.375"  Gr./Fy/Fu=A36/36.0/58 ksi

Flange plates:
 16"x7.75"x1.25"  Gr./Fy/Fu=US50/50.0/65 ksi

Plate to column welds:
 CJPGW fu=70 ksi web plate
 CJPGW fu=70 ksi top flange plate
 0.25" FW fu=70 ksi bottom flange plate
```

```
Bolts:
 2-1" A490PT/X each flange, 4" gauge.3" spacing.
 3-1" A490PT/X in shear plate at 3" spacing.

Stiffeners:  Gr./Fy/Fu=A36/36.0/58 ksi   Welds fu=70 ksi
 2/3.5" x0.25" top, 0.25" FW across ends.
 2/3.5" x0.25" btm., 0.25" FW and across ends.

Web doubler plates:
 18.622x11.457x0.3125  Gr./Fy/Fu=A36/36.0/58 ksi
 No. web doubler plates = 1
 Weld CJPGW fu=70 ksi all around.

MINIMUM ACTION CHECK
Specified minimum design actions:
 Bending       30% of øMs ( 4081.5)  = 1224.4 kip-in
 Shear                                  9.0 kip
 Tension        0% of øNs (  607.5)  =    0.0 kip
 Compression    0% of øNs (  607.5)  =    0.0 kip
 NOTE: Input design actions are not automatically increased if they are less than the
       specified minimum actions. Minimum actions may be set in any load case. This check
       warns if any design action is less than the specified minimum for all load cases.

INPUT DESIGN ACTIONS
 Moment, Mu  . . . . . .  2888.0 kip-in
 Shear, Vu . . . . . .    42.0 kip
 Axial, Nu . . . . . .     0.0 kip

Using AISC 2005 model...

GEOMETRY CHECKS...
For Special Moment Frame...
 ANSI/AISC 341-05 (Seismic Provisions) rules:
  Beam flange b/t ratio  . . . . . .     5.0  <=     7.2              Pass  A-341 8.2b
  Beam web h/t ratio . . . . . .    44.7  <=    59.0              Pass  A-341 8.2b
  Column flange b/t ratio  . . . . . .     7.1  <=     7.2              Pass  A-341 8.2b
 FEMA-350 prequalification rules:
  NOTE: SEAOC recommendations do not permit use of this connection type for IMF or SMF.
        The connection type is not included in ANSI/AISC 358-05 (IMF and SMF).
  Beam depth . . . . . .  18.10"  <   31.00"              Pass  F-350 T3-10
  Beam span to depth ratio . . . . . .    19.9  >=     8.0              Pass  F-350 T3-10
  Beam flange thickness  . . . . . .   0.61"  <=   0.75"              Pass  F-350 T3-10
  Beam yield stress  . . . . . .    50.0  >=    50.0              Pass  F-350 T3-10
                                          50.0  <     51.0              Pass  F-350 T3-10
  Column depth . . . . . .  14.70"  >=  11.00"              Pass  F-350 T3-10
                                         14.70"  <=  16.00"              Pass  F-350 T3-10
  Column yield stress  . . . . . .    50.0  >=    50.0              Pass  F-350 T3-10
  Flange plate yield stress  . . . . . .    50.0  >=    35.0              Pass  F-350 T3-10
                                          50.0  <=    51.0              Pass  F-350 T3-10
  Flange plate weld to column  . . . . . .   0.00"  =    0.00"              Pass  F-350 T3-10
  Bolt dia.  . . . . . .   1.00"  <=   1.13"              Pass  F-350 T3-10
  Bolt UTS . . . . . .    151   >=    120              Pass  F-350 T3-10
  Web bolt spacing, sp . . . . . .   3.00"  >=   3.00"              Pass  F-350 T3-10
  Flange plate bolt spacing, s2  . . . . . .   3.00"  >=   3.00"              Pass  F-350 T3-10

DESIGN STRENGTH CHECKS...
                                              Strength ratio --------+
                                              Reqd. strength -+      |
                                           +-- Design strength |     |
                                           |                  |     |
Beam:
 Flexural strength (tensile rupture) . . . .  2898.2  >  Mu    = 2888.0  1.00  Pass

Shear Plate:
 Shear strength of bolts . . . . . .   133.3  >  Vu    =   42.0  3.17  Pass
 Bearing strength of plate . . . . . .   117.5  >  Vu    =   42.0  2.80  Pass
 Tearing strength of plate . . . . . .    56.9  >  Vu    =   42.0  1.35  Pass
 Bearing strength of web . . . . . .   126.4  >  Vu    =   42.0  3.01  Pass
 Tearing strength of web . . . . . .   120.4  >  Vu    =   42.0  2.87  Pass
 Shear yielding strength . . . . . .    72.9  >  Vu    =   42.0  1.74  Pass  J4-3
 Shear rupture strength  . . . . . .    55.1  >  Vu    =   42.0  1.31  Pass  J4-4
 Block shear strength  . . . . . .    60.9  >  Vu    =   42.0  1.45  Pass  J4-5

Tension Flange Plate:
 Bolt design force . . . . . .   159.6 kip
 Shear strength of bolts . . . . . .   444.3  >  Puf   =  159.6  2.78  Pass
 Bearing strength of plate . . . . . .  1305.0  >  Puf   =  159.6  8.18  Pass
```

```
  Tearing strength of plate . . . . . .  1243.8  >  Puf   =  159.6  7.80  Pass
  Bearing strength of flange  . . . . . .   707.9  >  Puf   =  159.6  4.44  Pass
  Tearing strength of flange  . . . . . .   674.7  >  Puf   =  159.6  4.23  Pass
  Plate design force  . . . . . .  149.3 kip
  Tension yielding strength . . . . . .   435.9  >  Puf   =  149.3  2.92  Pass  D2-1
  Tension rupture strength  . . . . . .   299.1  >  Puf   =  149.3  2.00  Pass  D2-2
  Block shear strength of plate . . . . . .   725.9  >  Puf   =  149.3  4.86  Pass  J4-5
  Block shear strength of flange  . . . . . .   326.2  >  Puf   =  149.3  2.19  Pass  J4-5

 Compression Flange Plate:
  Plate design force  . . . . . .  149.3 kip
  Effective length (k=0.6)  . . . . . .  1.20 in.
  Compression strength of flange plate  . . .   435.6  >  Puf   =  149.3  2.92  Pass
  Compression yielding strength . . . . . .   435.9  >  Puf   =  149.3  2.92  Pass  D2-1

 SEISMIC DESIGN PROCEDURE...
 References:
  F-350 - FEMA-350: Recommended Seismic Design Criteria for New Steel Moment Frame Buildings
  SEAOC - Commentary and Recommendations on FEMA-350 - January 2002
  A-341 - ANSI/AISC 341-05: Seismic Provisions for Structural Steel Buildings
  A-358 - ANSI/AISC 358-05: Prequalified Connections for Special and Intermediate Steel
                            Moment Frames for Seismic Applications

  Peak strength coefficient, Cpr  . . . . . .    1.15                                F-350 3-2
  Beam yield ratio, Ryb . . . . . .    1.10                                A-341 I-6-1
  Probable plastic moment at hinge, Mpr . . .  5736.8 kip-in                       F-350 3-1
  Span (col. c/c), L  . . . . . .    360 in.
  Plastic hinge offset, Sh  . . . . . .  23.35 in.
  Distance between plastic hinges, L' . . . .    313 in.
  Shear at plastic hinge, Vp  . . . . . .    74.7 kip                              F-350 3.2.6
  Moment at column face, Mf . . . . . .  6932.4 kip-in                            F-350 3.2.6
  Moment at column centerline, Mc . . . . . .  7481.7 kip-in                       F-350 3.2.6
  Coefficient, Cy . . . . . .    0.76                                F-350 3-4
  Yield moment at column face, Myf  . . . . .  5237.3 kip-in                       F-350 3-3
  Column yield ratio, Ryc . . . . . .    1.10                                A-341 I-6-1
  Panel zone thickness, t . . . . . .   0.96"  >=   0.64"               Pass  F-350 3-7
  Flange plate thickness, tpl . . . . . .   1.25"  >=   0.86"               Pass  F-350 3-41
  Moment for shear failure of bolts . . . . .  10721 kip-in                       SEAOC 3-43
  1.2 Myf . . . . . .  6284.8  <    10721               Pass  F-350 3-42
  Moment for fracture of flange plate . . . .  6558.4 kip-in                       SEAOC 3-45
  1.2 Myf . . . . . .  6284.8  <   6558.4               Pass  F-350 3-42
  Fracture of beam flange, Znett/Z  . . . . .    0.74  >=    0.75               FAIL  SEAOC 3-47
  Bolt hole elongation force (flange) . . . .  1274.1 kip                          F-350 3-50
  Bolt hole elongation force (plate)  . . . .  2436.0 kip                          F-350 3-51
  Moment for elongation of bolt holes . . . .   24654 kip-in                       F-350 3-49
  1.2 Myf . . . . . .  6284.8  <    24654               Pass  F-350 3-42
  Flange plate block shear strength . . . . .   967.9 kip
  Beam flange block shear strength  . . . . .   434.9 kip
  Moment for block shear failure  . . . . . .  8416.0 kip-in
  1.2 Myf . . . . . .  6284.8  <   8416.0               Pass  F-350 3-42
  Seismic design shear  . . . . . .    82.2 kip                              F-350 3-52
  Shear Plate:
   Shear strength of bolts  . . . . . .   177.7  >  Vw    =   82.2  2.16  Pass
   Bearing strength of plate  . . . . . .   156.6  >  Vw    =   82.2  1.91  Pass
   Tearing strength of plate  . . . . . .    75.9  >  Vw    =   82.2  0.92  FAIL
   Bearing strength of web  . . . . . .   168.5  >  Vw    =   82.2  2.05  Pass
   Tearing strength of web  . . . . . .   160.6  >  Vw    =   82.2  1.95  Pass
   Shear yielding strength of plate . . . . .    72.9  >  Vw    =   82.2  0.89  FAIL  J4-3
   Shear rupture strength of plate  . . . . .    73.4  >  Vw    =   82.2  0.89  FAIL  J4-4
   Block shear strength of plate  . . . . . .    81.1  >  Vw    =   82.2  0.99  FAIL  J4-5

 +--------------------------------------------------------------------------+
 | WARNING: Connection does not satisfy all requirements of the model.      |
 |          Even if stated capacity is adequate the design may not be valid. |
 +--------------------------------------------------------------------------+

 CRITICAL LIMIT STATE . . .  Flexural strength (tensile rupture)
 UTILIZATION RATIO  . . . .    100%
 STRENGTH RATIO . . . . . .   1.004   Pass
```

Bolted Moment End Plate Connection

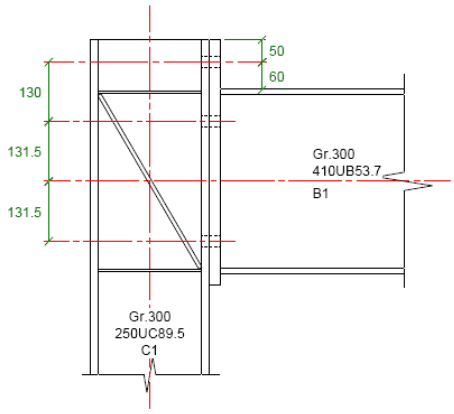


This is the design example from p. 115 of *Design of Structural Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Limcon V3.5

Engineering Systems Development
Job: BMEP p.115 -- Connection: BMEP
Bolted Moment End Plate Design Example
"Design of Structural Connections" p. 115

CONNECTION: BMEP - Bolted Moment End Plate
End plate: 200x25x540 Gr.250
Flange weld: FPBW/480/SP - Web weld: 6 FW/480/SP
Bolts: 6-M24 8.8/S/N in 2 cols. at 140 gauge



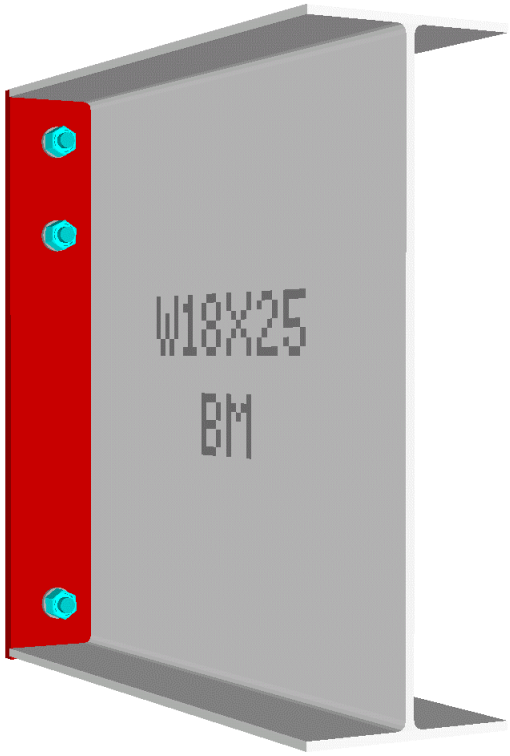
Stiffeners:
Top: 90x6x225.4 Gr.250 - Weld=5 FW/480/SP Side=none End=full
Shear: 90x8x439.8 Gr.250 - Weld=5 FW/480/SP Side=125 End=full
Btm.: 90x6x225.4 Gr.250 - Weld=5 FW/480/SP Side=full End=full

```
Geometry Check:
*** WARNING -- End plate side edge distance < 1.5 x dia.
 0 error(s), 1 warning(s)

LIMCON V3.5                                                    31-OCT-06
                                                                21:14:50

 Connection: BMEP
       Type: Bolted Moment End Plate Connection
             A - End plate square to beam
    Country: Australia
      Units: Metric
Design code: AS 4100 (ASI 2006)

Beam 1:  Mark=B1  Section=410UB53.7   Grade=300   Angle= 0.0 deg.
     D =   403 mm     Root rad. =   11.4 mm     fyf =  320 MPa
     B =   178 mm          Area = 6.8900E+03    fyw =  320 MPa
    Tf =  10.9 mm            Sx = 1.0600E+06     fu =  440 MPa
    Tw =   7.6 mm

Column:  Mark=C1  Section=250UC89.5   Grade=300
     D =   260 mm     Root rad. =   14.0 mm     fyf =  280 MPa
     B =   256 mm          Area = 1.1400E+04    fyw =  320 MPa
    Tf =  17.3 mm            Sx = 1.2300E+06     fu =  440 MPa
    Tw =  10.5 mm

End plate:
 540x200x25  Gr./fy/fu=250/250/410 MPa
 Beam to end plate angle, ø =  90.000 deg.

Beam welds:
 FPBW fu=480 MPa/SP flanges.
 6 FW fu=480 MPa/SP web.
```

```
Bolts:
 4-M24 8.8/S/N top flange, 140 gauge at 130 spacing.
 2-M24 8.8/S/N btm. flange, 140 gauge.
 Prying factor = 0.30

Stiffeners:  Gr./fy/fu=250/280/410 MPa   Welds fu=480 MPa/SP
 2/90 x6 top, 5 FW across ends.
 2/90 x6 btm., 5 FW full length and across ends.
 2/90 x8 shear, 5 FW 125 about midpoint and across ends.

MINIMUM ACTION CHECK
Specified minimum design actions:
 Bending       30% of øMs (  305.3)  =   91.6 kN.m
 Shear                               =   40.0 kN
 Tension        0% of øNs ( 1984.3)  =    0.0 kN
 Compression    0% of øNs ( 1984.3)  =    0.0 kN
 NOTE: Input design actions are not automatically increased if they are less than the
       specified minimum actions. Minimum actions may be set in any load case. This check
       warns if any design action is less than the specified minimum for all load cases.

INPUT DESIGN ACTIONS
 Beam 1:  Moment, M* . . . . . .   210.0 kN.m
          Shear, V*  . . . . . .   150.0 kN
          Axial, N*  . . . . . .     0.0 kN
 Column:  Shear, V*c . . . . . .  -100.0 kN
 Beam 2:  Moment, M* . . . . . .    0.00 kN.m
          Shear, V*  . . . . . .     0.0 kN
          Axial, N*  . . . . . .     0.0 kN

Using AS1 1994 model...

ANALYSIS RESULT
Elastic analysis:
 Beam 1...            Nft  =   435.6t   Nfc  =   435.6c
                      Nwt  =     0.0    Nwc  =     0.0
                      Mw   =    39.2
Plastic analysis:
 Beam 1...            Nft  =   424.5t   Nfc  =   424.5c
                      Nwt  =     0.0    Nwc  =     0.0
                      Mw   =    43.5
Simplified analysis:
 Beam 1...            Nft  =   535.6t   Nfc  =   535.6c
                      Nwt  =     0.0    Nwc  =     0.0
                      Mw   =    0.00

NOTE: Elastic analysis results used.

DESIGN CAPACITY CHECKS...
                                                  Capacity ratio --------+
                                                  Design action --+      |
                                                +-- Design capacity |    |
                                                |                   |    |
Flanges:
 Flange tension capacity . . . . . .   558.8  >  N*ft  =  435.6  1.28  Pass
 Flange compression capacity . . . . .  558.8  >  N*fc  =  435.6  1.28  Pass

Flange welds:
 Using full penetration butt weld, fu=480 /SP...
 Flange FPBW  tension capacity . . . . .   558.8  >  N*ft  =  435.6  1.28  Pass
 Flange FPBW  compression capacity . . . .  558.8  >  N*fc  =  435.6  1.28  Pass

Web:
 Shear capacity (non-slender web)  . . . .  529.3  >  V*    =  150.0  3.53  Pass

Web welds:
 Web shear force . . . . . .   150.0 kN
 Web bending moment  . . . . .    39.2 kN.m
 Using 6 fillet weld, fu=480 /SP, both sides...
 Web fillet weld capacity  . . . . . .   0.978  >  v*max =  0.833  1.17  Pass

Bolts: M24
 Bolt UTS  . . . . . .    830   >=    827               Pass
WARNING: Bolts must be tensioned.
 Tensile strength  . . . . . .   234.4 kN

Beam 1
 Bolt group tension  . . . . . .   535.6 kN
```

```
 Bolt group shear force  . . . . .   150.0 kN

 Bolt group tension capacity (incl. prying)    721.2  >  N*ft  =  535.6  1.35  Pass
 No. bolts in compression region .       2
 Bolt shear capacity . . . . . .   266.8  >  V*    =  150.0  1.78  Pass
 Plate bearing capacity  . . . . . .  1417.0  >  V*    =  150.0  9.45  Pass
 Column flange bearing capacity  . . . . . .  1052.3  >  V*    =  150.0  7.02  Pass

End plate:
 540x200x25  Gr./fy/fu=250/250/410 MPa
 End plate flexural capacity . . . . . .   585.9  >  N*ft  =  535.6  1.09  Pass
 End plate shear capacity  . . . . . .  1125.0  >  V*    =  150.0  7.50  Pass

Column stiffening...

Tension flange - top
 Unstiffened capacity  . . . . . .   558.7  >  N*ft  =  535.6  1.04
 Stiffener required due to overlapping stress regions.

Compression flange - bottom
 Unstiffened capacity  . . . . . .   657.4  >  N*fc  =  535.6  1.23
 Stiffener required due to overlapping stress regions.

Shear stiffening
 Column design shear . . . . . .   435.6 kN
 Unstiffened capacity  . . . . . .   409.0  >  N*fv  =  435.6  0.94
 Stiffener design force  . . . . .    54.5 kN
 Using two 90 x8 stiffeners, fy=280 ...
 Stiffener yield capacity  . . . . . .   362.9  >  N*st  =   54.5  6.66  Pass
 Using 5 fillet weld, fu=480 /SP
  welding middle 125 on both sides of each stiffener...
 Stiffener weld capacity . . . . . .   407.3  >  N*st  =   54.5  7.47  Pass
 Stiffener buckling capacity . . . . . .   305.1  >  N*st  =   54.5  5.60  Pass

CRITICAL LIMIT STATE . . .  End plate flexural capacity
UTILIZATION RATIO  . . . .     91%
CAPACITY RATIO, ø.Ru/S* .    1.094   Pass
```

Multiple Row Flush End Plate Moment Connection

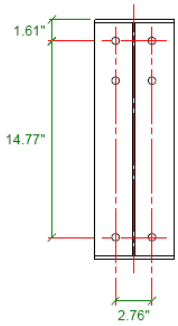


This is the design example from p. 24 of Ref. 18, *Flush and Extended Multiple-Row Moment End Plate Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Limcon V3.5

Engineering Systems Development
Job: MEPC P.24 -- Connection: P.24
Flush Moment End Plate Connection Design Example
AISC Steel Design Guide 16 p. 24

CONNECTION: P.24 - AISC Moment End Plate Connection
Member: BM W18X25 Gr.A588
End plate: 6"x0.437"x18" Gr.US50



Flange weld: 0.315" FW/70ksi - Web weld: 0.315" FW/70ksi
Bolts: 4-1/2" A325ST/N at 2.7559" gauge

```
LIMCON V3.5                                                          31-OCT-06
                                                                      21:37:43
 Connection: P.24
       Type: Moment End Plate Connection
             Flush end plate - 2: 4 bolt unstiffened
    Country: US
      Units: US customary
Design code: ANSI/AISC 360-05 (LRFD)

Beam:  Mark=BM  Section=W18X25   Grade=A588
     D = 18.00 in.   Root rad. =   0.25 in.   fyf = 50.0 ksi
     B =  6.00 in.        Area = 7.4286E+00   fyw = 50.0 ksi
    Tf =  0.25 in.          Zx = 4.6232E+01    fu = 70.0 ksi
    Tw =  0.25 in.

End plate:
 18"x6"x0.437"  Gr./Fy/Fu=US50/50.0/65 ksi

Beam welds:
 0.315" FW fu=70 ksi flanges.
 0.315" FW fu=70 ksi web.

Bolts:
 4-1/2" A325ST/N top flange, 2.755 gauge at 3.346 spacing.
 2-1/2" A325ST/N btm. flange, 2.755 gauge.

MINIMUM ACTION CHECK
Specified minimum design actions:
 Bending       30% of øMs ( 2080.4)  =  624.1 kip-in
 Shear                                    9.0 kip
 Tension        0% of øNs (  334.3)  =    0.0 kip
 Compression    0% of øNs (  334.3)  =    0.0 kip
 NOTE: Input design actions are not automatically increased if they are less than the
```

```
       specified minimum actions. Minimum actions may be set in any load case. This check
       warns if any design action is less than the specified minimum for all load cases.
 WARNING: Design shear force is less than specified minimum.

INPUT DESIGN ACTIONS
 Moment, Mu  . . . . . . . . . . . . . . . .   783.3 kip-in
 Shear, Vu . . . . . . . . . . . . . . . . .     0.0 kip
 Axial, Nu . . . . . . . . . . . . . . . . .     0.0 kip

Using AISC 2002 model...

GEOMETRY CHECKS...
Bolts: 1/2"
 Bolt UTS  . . . . . . . . . . . . . . . . .    120   >=    120               Pass
 Tensile strength (MEPC model) . . . . . . .    13.3 kip
 Specified minimum tension . . . . . . . . .     0.0 kip
 Assumed tension (Ref. 18) . . . . . . . . .    13.3 kip

Table 3-6 - Tested parameter ranges:
 (Ref. "Flush and Extended Multiple Row Moment End Plate Connections"
       T.M. Murray & W.L. Shoemaker
       American Institute of Steel Construction - 2002)
 pf  . . . . . . . . . . . . . . . . . . . .   1.36"  >=   1.31"              Pass
                                               1.36"  <=   1.88"              Pass
 pb  . . . . . . . . . . . . . . . . . . . .   2.99"  >=   1.88"              Pass
                                               2.99"  <=   3.00"              Pass
 g . . . . . . . . . . . . . . . . . . . . .   2.76"  >=   2.25"              Pass
                                               2.76"  <=   3.75"              Pass
 h . . . . . . . . . . . . . . . . . . . . .  18.00"  >=  16.00"              Pass
                                              18.00"  <=  24.00"              Pass
 bp  . . . . . . . . . . . . . . . . . . . .   6.00"  >=   5.00"              Pass
                                               6.00"  <=   6.00"              Pass
 tf  . . . . . . . . . . . . . . . . . . . .   0.25"  >=   0.19"              Pass
                                               0.25"  <=   0.38"              Pass

DESIGN STRENGTH CHECKS...
                                                    Strength ratio --------+
                                                    Reqd. strength -+      |
                                                +-- Design strength |      |
                                                |                   |      |
End plate yield line analysis:
 End plate yield strength  . . . . . . . . .  1092.4 kip-in
 Bolt rupture strength (no prying) . . . . .   782.8 kip-in
 Thick plate behaviour governs...
 Bolt rupture strength (no prying) . . . . .   782.8  >  Mu    =  783.3  1.00  Pass

Flanges:
 Flange tension strength . . . . . . . . . .    67.5  >  Nuft  =   44.1  1.53  Pass
 Flange compression strength . . . . . . . .    67.5  >  Nufc  =   44.1  1.53  Pass

Flange welds:
 Maximum flange force  . . . . . .    44.1 kip
 Flange yield strength . . . . . . . . . . .    56.3 kip
 Minimum weld design force . . . .    33.8 kip
 Flange weld design force  . . . .    44.1 kip
 Using 0.315" fillet weld, fu=70.1, all around...
 Flange fillet weld tension strength . . . .    84.2  >  Nuft  =   44.1  1.91  Pass
 Flange fillet weld compression strength . .    84.2  >  Nufc  =   44.1  1.91  Pass

Web shear:
 Web depth between flanges . . . .  17.50 in.
 Web depth for shear resistance  .   8.75 in.
 Beam web shear strength . . . . . . . . . .    49.2  >  Vu    =    0.0  0.00  Pass

Web welds:
 Weld depth for shear resistance .   8.75 in.
 Using 0.315" fillet weld, fu=70.1, both sides...
 Web fillet weld shear strength (2 sides)  .   122.9  >  Vu    =    0.0  0.00  Pass
 Section web axial capacity  . . . . . . . .  11.250 kip/in
 Minimum weld design force . . . .   6.750 kip/in
 Section moment/capacity ratio . .   0.377
 Web weld design force . . . . . .   6.750 kip/in
 Using 0.315" fillet weld, fu=70.1, both sides...
 Web fillet weld axial strength (2 sides)  .  14.041  >  nuw   =  6.750  2.08  Pass

Bolts:
 Shear strength of compression bolts . . . .    14.1  >  Vu    =    0.0  0.00  Pass
```

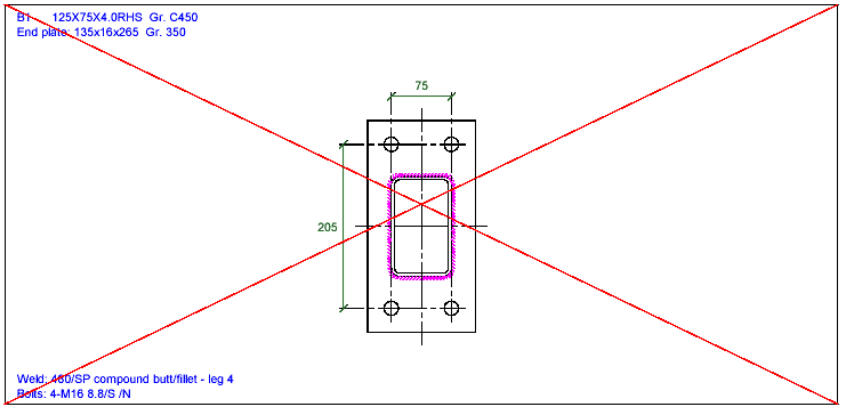
```
  End plate ply bearing strength  . . . . . .    51.1  >  Vu    =    0.0  0.00  Pass

 CRITICAL LIMIT STATE . . .  Bolt rupture strength (no prying)
 UTILIZATION RATIO  . . . .    100%
 STRENGTH RATIO . . . . . .   0.999   Pass
```

4-Bolt RHS Moment End Plate Connection

This is Design Example 1 from Ref. 27, *Design Model for Bolted Moment End Plate Connections Using Rectangular Hollow Sections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

The Ref. 27 design model uses a “plate design stress”, which is a function of yield and ultimate stresses, rather than the yield stress used throughout Limcon for evaluation of strength limit state capacities. If Limcon used this value (416 MPa) instead of the correct yield stress (340 MPa), the bolt failure and plate failure capacities obtained would be 23.0 kN.m and 26.8 kN.m, respectively. These compare favourably with the published values of 22.2 kN.m and 25.9 kN.m. The values in the Limcon output below, 20.6 kN.m and 21.4 kN.m, both exceed the design moment capacity of the section, 19.0 kN.m. The connection is shown as failing the design checks only because the design moment of 22.2 kN.m was chosen to match the capacity in the published design example.

Engineering Systems Development
Job: TMEP4-R745 -- Connection: R745-1
4-Bolt RHS Moment End Plate Connection Design Example
University of Sydney C.A.S.E. R745 Example 1

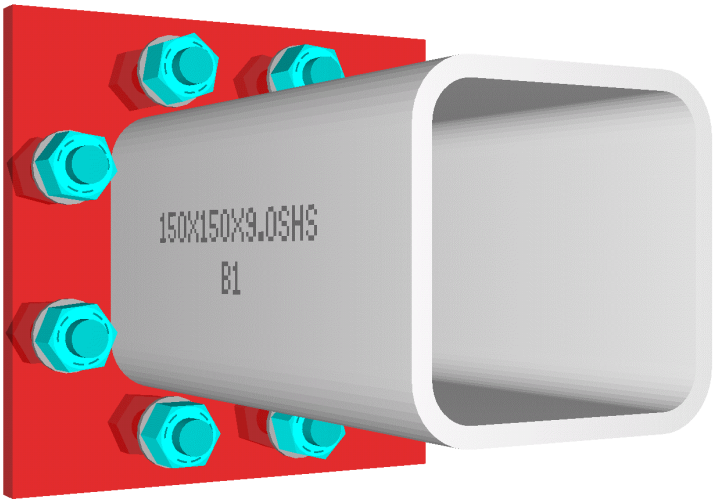



```
LIMCON V3.0                                                    13-DEC-02
                                                                11:14:22

 Connection: R745-1
       Type: RHS bolted moment end plate
Design code: AS4100/NZS3404

Member:  Mark=B1   Section=125X75X4.0RHS   Grade=C450
     D =  125.0          Area =  1.480E+03    fy = 400
     B =   75.0            Sx =  6.030E+04    fu = 500
     T =    4.0

End plate:
 265x135x16  Gr./fy/fu=350/340/480

Weld:
 4 CFB/480/SP all around section.

Bolts:
 4-M16 8.8/S /N edge dist. 30 gauge 10

Input design actions:
 Moment          22.2
 Shear            0.0
 Axial            0.0

Minimum design actions:
 Bending        0% of ø.Ms  (   21.7)  =     0.0 kN.m
 Shear                                    0.0 kN
 Tension        0% of ø.Ns  (  532.8)  =     0.0 kN
 Compression    0% of ø.Ns  (  532.8)  =     0.0 kN

ANALYSIS RESULT

Final design actions:
 Moment  . . . . . . . . . . . . . . . . . .    22.2
 Shear . . . . . . . . . . . . . . . . . . .     0.0
 Tension . . . . . . . . . . . . . . . . . .     0.0
```

Engineering Systems Development
Job: TMEP4-R745 -- Connection: R745-1
4-Bolt RHS Moment End Plate Connection Design Example
University of Sydney C.A.S.E. R745 Example 1

```
Tested parameter ranges:
 Depth of beam section . . . . . .   125.0  <=   400.0         Pass
 Section slenderness plasticity limit  . . .    30.0
 Section slenderness yield limit . . . . . .    40.0
 Section slenderness . . . . . .    21.2
  Compactness = C - Pass

 Horiz. distance from web to bolt, c . . . .       0
 Vert. distance from flange to bolt, so  . .      40

Yield line analysis:
 Mode 1 failure moment . . . . . .    22.7
 Mode 2 failure moment . . . . . .    22.7
 Mode 3 failure moment . . . . . .    36.2
 Plate equivalent width  . . . . . .   135.0

Bending:
 Bolt tension failure capacity . . . . . .    20.6  <  M*    =   22.2  FAIL
 End plate failure capacity  . . . . . .    21.4  <  M*    =   22.2  FAIL

Bolts:
 Shear capacity of compression bolts . . . .   118.6  >  V*    =    0.0  Pass
 End plate ply bearing capacity  . . . . . .   707.8  >  V*    =    0.0  Pass

Serviceability limit states:
 Bolt yielding serviceability capacity . . .    19.1  >  M     =   14.8  Pass
 Plate yielding serviceability capacity  . .    20.6  >  M     =   14.8  Pass

NOTE: Specified combination fillet/butt weld does not require checking.

Critical limit state:  Bolt tension failure capacity
            ø.Ru/S*:    0.929   FAIL  ****
```

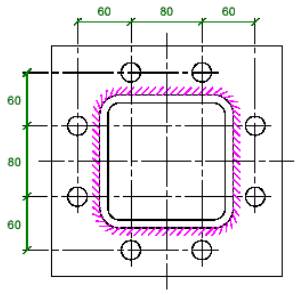
8-Bolt RHS Moment End Plate Connection



This is Test 7 from Ref. 28, *Design Model for Bolted Moment End Plate Connections Joining Rectangular Hollow Sections Using Eight Bolts*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Engineering Systems Development
Job: TMEP8 #1-#10 -- Connection: 7
8-Bolt RHS Moment End Plate Connection Design Example
University of Sydney C.A.S.E. Research Report Test 7

B1 150X150X9.0SHS Gr. C350
End plate: 260x16x260 Gr. 350



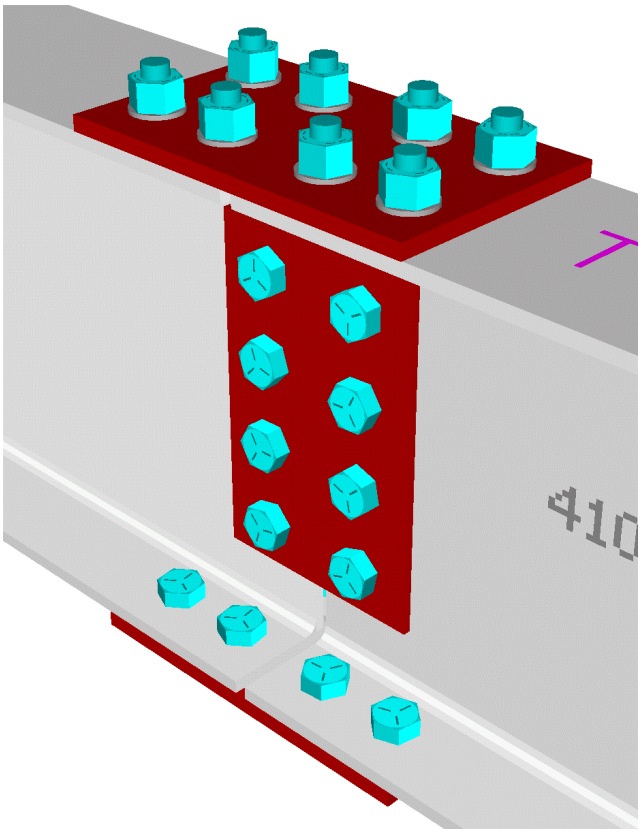
Weld: 480/SP compound butt/fillet - leg 8
Bolts: 8-M20 8.8/S /N

```
LIMCON V3.0                                                    13-DEC-02
                                                                12:46:22

 Connection: 7
       Type: RHS bolted moment end plate
Design code: AS4100/NZS3404

Member:  Mark=B1   Section=150X150X9.0SHS   Grade=C350
     D =  150.0          Area =  4.800E+03    fy = 350
     B =  150.0            Sx =  2.480E+05    fu = 430
     T =    9.0

End plate:
 260x260x16  Gr./fy/fu=350/340/480

Weld:
 8 CFB/480/SP all around section.

Bolts:
 8-M20 8.8/S /N edge dist. 30 gauge 35

Input design actions:
 Moment          78.1
 Shear            0.0
 Axial            0.0

Minimum design actions:
 Bending        0% of ø.Ms   (   78.1)  =     0.0 kN.m
 Shear                                    0.0 kN
 Tension        0% of ø.Ns   ( 1512.0)  =     0.0 kN
 Compression    0% of ø.Ns   ( 1512.0)  =     0.0 kN

ANALYSIS RESULT

Final design actions:
 Moment  . . . . . . . . . . . . . . . . . .    78.1
 Shear . . . . . . . . . . . . . . . . . . .     0.0
 Tension . . . . . . . . . . . . . . . . . .     0.0
```

Engineering Systems Development
Job: TMEP8 #1-#10 -- Connection: 7
8-Bolt RHS Moment End Plate Connection Design Example
University of Sydney C.A.S.E. Research Report Test 7

```
Tested parameter ranges:
 Depth of beam section . . . . . .   150.0  <=   400.0         Pass
 Section slenderness plasticity limit  . . .    30.0
 Section slenderness yield limit . . . . . .    40.0
 Section slenderness . . . . . . . . . . . .    17.4
  Compactness = C - Pass

 Horiz. distance from web to bolt  . . . . .      25
 Vert. distance from flange to bolt, so  . .      25

Yield line analysis:
 Mode 1  . . . . . .   0.0
 Mode 2  . . . . . .   155.6
 Mode 6  . . . . . .   111.4

Bending:
 Thick plate capacity  . . . . . .    95.0  >  M*    =   78.1  Pass
 Intermediate plate capacity 1 . . . . . .   118.2
 Intermediate plate capacity 2 . . . . . .   105.5
 Intermediate plate capacity . . . . . .   105.5  >  M*    =   78.1  Pass
 Thin plate capacity . . . . . .   163.3  >  M*    =   78.1  Pass
 Bolt tension yield capacity . . . . . .   103.6  >  M*    =   78.1  Pass
 Section yield capacity  . . . . . .    78.1  >  M*    =   78.1  Pass
 Punching shear failure  . . . . . .   105.4  >  M*    =   78.1  Pass

Bolts:
 Shear capacity of compression bolts . . . .   370.5  >  V*    =    0.0  Pass
 End plate ply bearing capacity  . . . . . .  1769.5  >  V*    =    0.0  Pass

NOTE: Specified combination fillet/butt weld does not require checking.

Critical limit state:  Section yield capacity
            ø.Ru/S*:    1.000   Pass
```

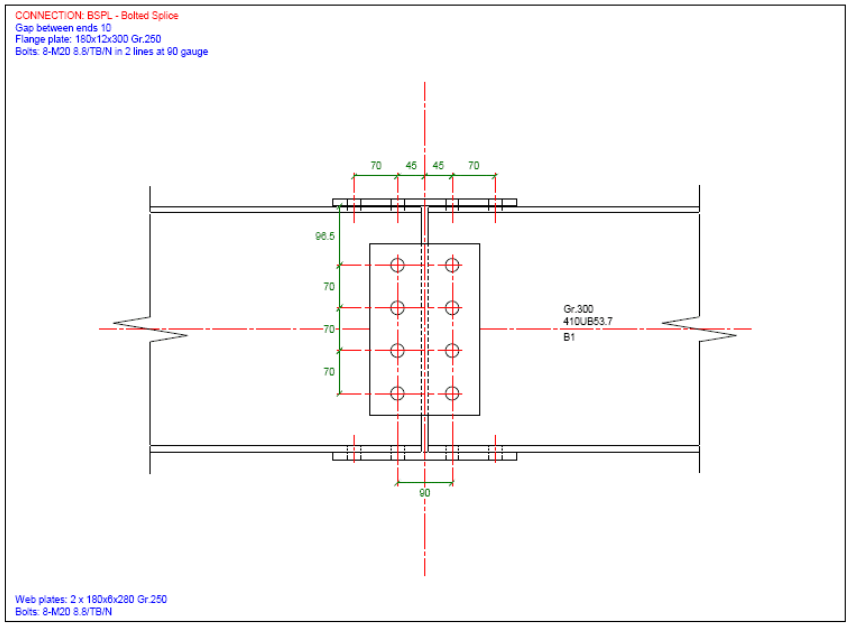
Bolted Splice



This is the design example from p. 142 of *Design of Structural Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Limcon V3.5

Engineering Systems Development
Job: BSPL p.142 -- Connection: BSPL
Bolted Splice Design Example
"Design of Structural Connections" p. 142

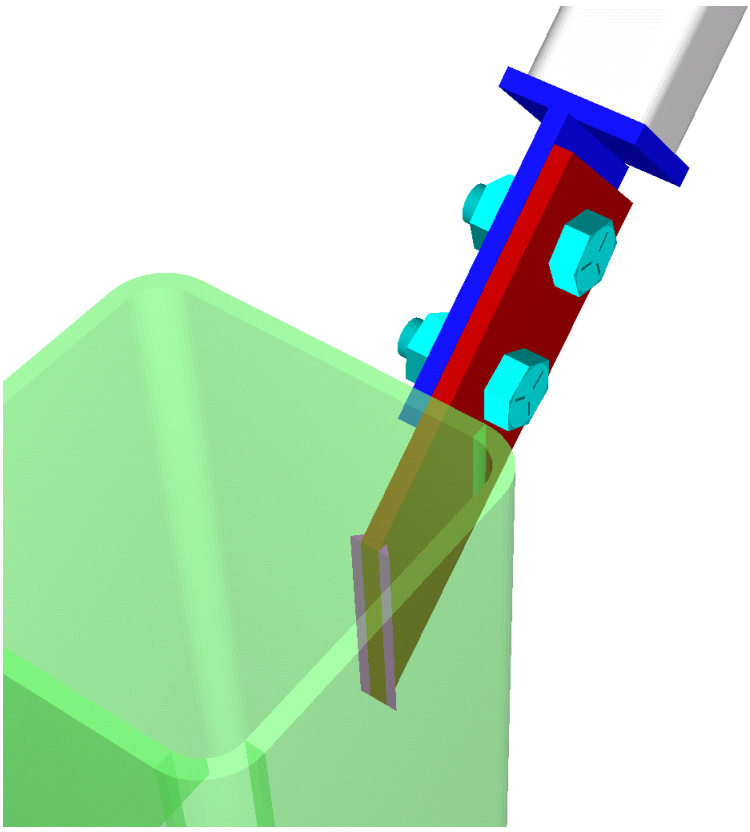



```
Geometry Check:
*** WARNING -- Plate width > beam flange width.
 0 error(s), 1 warning(s)

LIMCON V3.5                                                    31-OCT-06
                                                                17:37:40
 Connection: BSPL
       Type: Bolted Splice
    Country: Australia
      Units: Metric
Design code: AS 4100 (ASI 2006)

Member:  Mark=B1  Section=410UB53.7   Grade=300
     D =   403 mm     Root rad. =   11.4 mm    fyf =  320 MPa
     B =   178 mm          Area = 6.8900E+03   fyw =  320 MPa
    Tf =  10.9 mm            Sx = 1.0600E+06    fu =  440 MPa
    Tw =   7.6 mm

 Gap between ends = 10

Flanges: 300x180x12 splice plates (ext.)  Gr./fy/fu=250/260/410 MPa
         Bolts: 8-M20 8.8/TB/N ea. flange in 2 lines and 2 rows each side.
         90 across gap, 70 between rows, 90 gauge.

Web:     2/280x180x6 splice plates  Gr./fy/fu=250/280/410 MPa
         Bolts: 8-M20 8.8/TB/N in 4 rows and 1 col(s). each side,
         90 across gap, 70 between columns, 70 between rows.

MINIMUM ACTION CHECK
Specified minimum design actions:
 Bending       30% of øMs (  305.3)  =   91.6 kN.m
 Shear                               =   40.0 kN
 Tension        0% of øNs ( 1984.3)  =    0.0 kN
```

```
 Compression    0% of øNs ( 1984.3)  =    0.0 kN
 NOTE: Input design actions are not automatically increased if they are less than the
       specified minimum actions. Minimum actions may be set in any load case. This check
       warns if any design action is less than the specified minimum for all load cases.

DESIGN CHECK SUMMARY
 Case     M*      V*      N*       LF    Util.
   1       80      50       0     1.59     63%
   2     91.6      40       0     1.45     69%  <-- Critical

INPUT DESIGN ACTIONS FOR CASE NO.    2
 Moment, M*  . . . . . . . . . . . . . . . .    91.6 kN.m
 Shear, V* . . . . . . . . . . . . . . . . .    40.0 kN
 Axial, N* . . . . . . . . . . . . . . . . .     0.0 kN

Using ASI 1994 model...

ANALYSIS RESULT
Elastic analysis:     Nft  =   190.0t   Nfc  =   190.0c
                      Nwt  =     0.0    Nwc  =     0.0
                      Mw   =    17.1

Plastic analysis:     Nft  =   185.2t   Nfc  =   185.2c
                      Nwt  =     0.0    Nwc  =     0.0
                      Mw   =    19.0

Simplified analysis:  Nft  =   233.6t   Nfc  =   233.6c
                      Nwt  =     0.0    Nwc  =     0.0
                      Mw   =    0.00

NOTE: Elastic analysis results used.

Flange and web derived design actions...

Flange forces:
 Due to axial forces  Nft  =     0.0    Nfc  =     0.0
 Due to moment        Nfm  =   190.0
 Total flange forces  Nft  =   190.0t   Nfc  =   190.0c
 Flange plate forces  Nft  =   190.0t   Nfc  =   190.0c

Web forces:
 Axial                Nwt  =     0.0    Nwc  =     0.0
 Shear                Vw   =    40.0
 Eccentricity moment  Mwe  =    1.80
 Total moment         Mw   =    18.9

DESIGN CAPACITY CHECKS...
                                                 Capacity ratio --------+
                                                 Design action --+      |
                                               +-- Design capacity |    |
                                               |                   |    |
Flanges:
 Flange tension capacity . . . . . . . . . .   491.6  >  N*ft  =  190.0  2.59  Pass
 Flange compression capacity . . . . . . . .   558.8  >  N*fc  =  190.0  2.94  Pass

Flange plates:
 Flange plate tension capacity . . . . . . .   505.4  >  N*ft  =  190.0  2.66  Pass
 Flange plate compression capacity . . . . .   505.4  >  N*fc  =  190.0  2.66  Pass

Flange bolts:
 Shear capacity (plate tension)  . . . . . .   370.5  >  N*fmx =  190.0  1.95  Pass
 Shear capacity (plate compression)  . . . .   370.5  >  N*fc  =  190.0  1.95  Pass
 Flange bearing capacity . . . . . . . . . .  1105.0  >  N*fmx =  190.0  5.82  Pass
 Flange tearing capacity . . . . . . . . . .   673.4  >  N*ft  =  190.0  3.54  Pass
 Plate bearing capacity  . . . . . . . . . .  1133.6  >  N*fmx =  190.0  5.97  Pass
 Plate tearing capacity  . . . . . . . . . .   602.2  >  N*ft  =  190.0  3.17  Pass

Web plates:
 Shear yield capacity  . . . . . . . . . . .   508.0  >  V*w   =   40.0  12.7  Pass
 Shear rupture capacity  . . . . . . . . . .   510.1  >  V*w   =   40.0  12.8  Pass
 Tension yield capacity  . . . . . . . . . .   846.7  >  N*wt  =    0.0  0.00  Pass
 Tension rupture capacity  . . . . . . . . .   722.6  >  N*wt  =    0.0  0.00  Pass
 Compression capacity  . . . . . . . . . . .   846.7  >  N*wc  =    0.0  0.00  Pass
 Moment capacity . . . . . . . . . . . . . .    59.3  >  M*w   =   18.9  3.14  Pass
 Moment+axial capacity . . . . . . . . . . .    59.3  >  M*w   =   18.9  3.14  Pass

Web bolts (right-hand group):
```

```
 Web checks...
 Bolt shear (critical bolt row, column)...
  Bolt shear . . . . . . . . . . . . . . (1,1)   185.3  >  V*res =   81.6  2.27  Pass
 Bolt bearing/tearing (critical bolt row column)...
  Bolt bearing . . . . . . . . . . . . . (1,1)   192.6  >  V*res =   81.6  2.36  Pass
  Bolt group ext. tearing (left) . . . (4,1)   117.4  >  V*h   =   81.0  1.45  Pass
  Bolt group int. tearing (vert.)  . . (1,1)   174.6  >  V*v   =   10.0  17.5  Pass
 Web plate checks...
 Bolt shear (critical bolt row, column)...
  Bolt shear . . . . . . . . . . . . . . (1,1)   185.3  >  V*res =   81.6  2.27  Pass
 Bolt bearing/tearing (critical bolt row column)...
  Bolt bearing . . . . . . . . . . . . . (1,1)   283.4  >  V*res =   81.6  3.47  Pass
  Bolt group ext. tearing (top)  . . . (1,1)   150.6  >  V*v   =   10.0  15.1  Pass
  Bolt group ext. tearing (left) . . . (1,1)   345.4  >  V*h   =   81.0  4.27  Pass
  Bolt group ext. tearing (right)  . . (4,1)   194.8  >  V*h   =   81.0  2.41  Pass
  Bolt group int. tearing (vert.)  . . (2,1)   256.8  >  V*v   =   10.0  25.7  Pass

CRITICAL LOAD CASE . . . .       2
CRITICAL LIMIT STATE . . .   Bolt group ext. tearing (left)
UTILIZATION RATIO  . . . .     69%
CAPACITY RATIO, ø.Ru/S* .    1.450   Pass
```

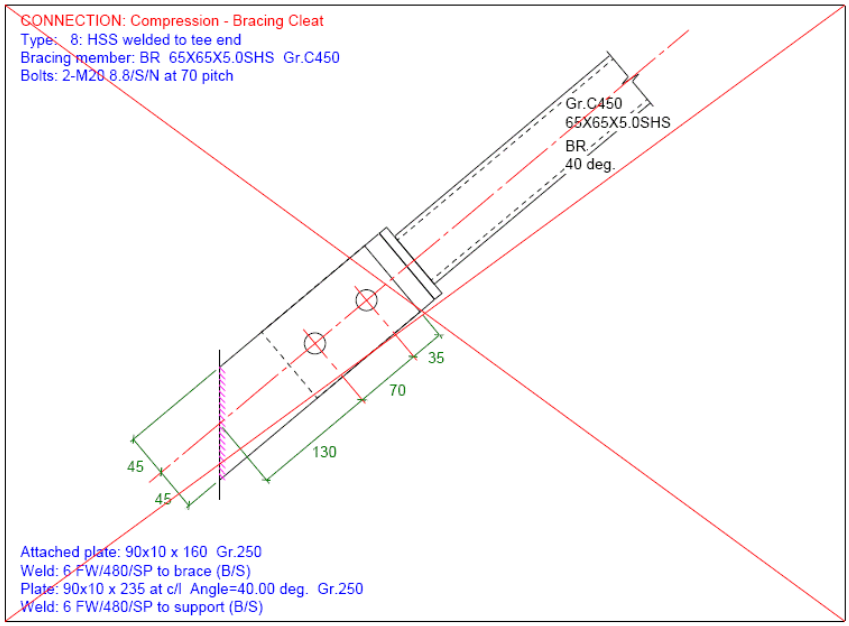
Bracing Cleat



This is the design example from p. 6-21 of *Design of Structural Steel Hollow Section Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Limcon V3.5

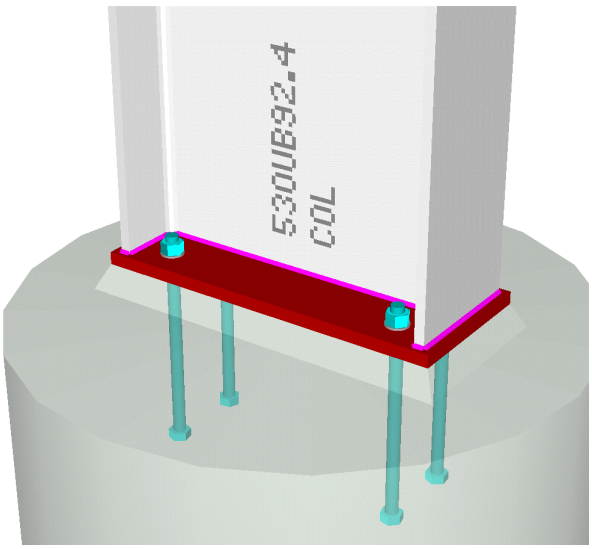
Engineering Systems Development
Job: Ex. p6-21 -- Connection: Compression
Bracing Cleat Design Example
"Design of Structural Steel Hollow Section Connections" p. 6-21




```
LIMCON V3.5                                                    31-OCT-06
                                                               16:39:35

 Connection: Compression
       Type: Bracing Cleat Connection
             8: HSS welded to tee end
    Country: Australia
      Units: Metric
Design code: AS 4100 (ASI 2006)

Brace:  Mark=BR  Section=65X65X5.0SHS   Grade=C450
     D =  65.0 mm          Area = 1.1100E+03    fy =  450 MPa
     B =  65.0 mm            Sx = 2.4300E+04    fu =  500 MPa
     T =   5.0 mm
 Angle between brace and normal to support = 40.00 deg.

Attached plate:
 160x90x10  Gr./fy/fu=250/260/410 MPa
 Weld 6 FW fu=480 MPa/SP

Support:  Section=200X200X9.0SHS   Grade=C350
     D =   200 mm          Area = 6.6000E+03    fy =  350 MPa
     B =   200 mm            Sx = 4.6500E+05    fu =  430 MPa
     T =   9.0 mm

Cleat (gusset):
 235x90x10  Gr./fy/fu=250/260/410 MPa
 Whitmore section  . . . . . .   80.8 mm
 Bolts 2-M20 8.8/S/N at 70 pitch.
 Weld 6 FW fu=480 MPa/SP to support.

Clearances:
 Clearance between brace/cleat and column  .   43.8 mm
 Clearance between brace and cleat . . . . .   20.0 mm
```

```
MINIMUM ACTION CHECK
Specified minimum design actions:
 Tension       0% of øNs (  449.5)  =    0.0 kN
 Compression   0% of øNs (  449.5)  =    0.0 kN
 NOTE: Input design actions are not automatically increased if they are less than the
       specified minimum actions. Minimum actions may be set in any load case. This check
       warns if any design action is less than the specified minimum for all load cases.

INPUT DESIGN ACTIONS
 Axial, N* . . . . . .   -70.0 kN  (comp.)
WARNING: This connection type may not be suitable for short compression members.

Using ASI 1994/1996 model...

DESIGN CAPACITY CHECKS - Compression
                                                  Capacity ratio ---------+
                                                  Design action --+       |
                                              +-- Design capacity |       |
                                              |                   |       |
Bracing member:
 Section compression capacity  . . . . . .   449.6  >  N*    =   70.0  6.42  Pass

Bolts:
 Bolt group shear capacity . . . . . .       185.3  >  N*    =   70.0  2.65  Pass

Bracing cleat (gusset):
 Cleat bearing capacity  . . . . . .         472.3  >  N*    =   70.0  6.75  Pass
 Cleat internal tearing capacity . . . . .   428.0  >  N*    =   70.0  6.11  Pass
 Cleat weld capacity . . . . . .             229.7  >  N*    =   70.0  3.28  Pass

Attached plate (gusset plate):
 Plate bearing capacity  . . . . . .         472.3  >  N*    =   70.0  6.75  Pass
 Plate internal tearing capacity . . . . .   428.0  >  N*    =   70.0  6.11  Pass

Welded tee end cap - compression:
 Cap plate bearing on HSS end  . . . . . .   291.6  >  N*    =   70.0  4.17  Pass
 Strength of the HSS wall  . . . . . .       292.5  >  N*    =   70.0  4.18  Pass
 Cap plate to HSS weld capacity  . . . . .   140.8  >  N*    =   70.0  2.01  Pass
 Attached plate to cap plate weld  . . . .   146.6  >  N*    =   70.0  2.09  Pass

Eccentrically connected plates:
 Effective width . . . . . .    90.0 mm
 Effective thickness . . . . . .   10.0 mm
 Eccentricity  . . . . . .         10.0 mm
 Cleat fraction of moment  . . . .   0.50
 Effective length (k=1.0)  . . . .   255 mm
  Equiv. column elastic buckling load  . . .  227.7 kN                              Cl.4.6.2
  Equiv. column compression capacity . . . .  128.3 kN                              Cl.6.3.3
  Equiv. column section bending capacity . .    0.5 kN                              Cl.5.2.1
 At eccentric cleat capacity...
  Eccentricity moment  . . . . . .            0.50 kN.m
  Moment amplification factor  . . . . . .    1.28
  Maximum cleat bending moment . . . . . .    0.32 kN.m
  Cleat compression capacity . . . . . .    128.3 kN
  Section moment capacity  . . . . . .       0.53 kN.m
  Reduced section moment capacity  . . . .    0.40 kN.m
  In-plane cleat moment capacity . . . . .    0.32 kN.m
 Capacity of eccentric cleat (Ref. 4)  . . .   49.9  >  N*    =   70.0  0.71  FAIL  8.4.2.2
 Capacity ignoring eccentricity  . . . . . .  128.3  >  N*    =   70.0  1.83  Pass  Informative
 Capacity of eccentric cleat (Ref. 12) . . .  112.2  >  N*    =   70.0  1.60  Pass  Informative
 Yield capacity of eccentric cleat . . . . .  210.6  >  N*    =   70.0  3.01  Pass  Informative

HSS support member:
 HSS support member wall shear capacity  . .  621.8  >  N*    =   70.0  8.88  Pass
 SHS Column face yielding capacity . . . . .  197.6  >  N*    =   70.0  2.82  Pass

CRITICAL LIMIT STATE . . .  Capacity of eccentric cleat (Ref. 4)
UTILIZATION RATIO  . . . .    140%
CAPACITY RATIO, ø.Ru/S* .    0.713   FAIL  ****
```

Pinned Base Plate

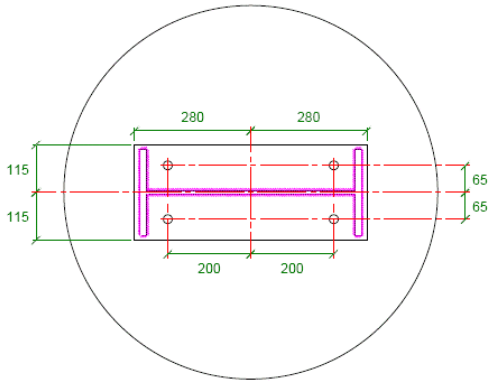


This is the design example from p. 162 of *Design of Structural Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Limcon V3.5

Engineering Systems Development
Job: BASE p.162 -- Connection: BASE
Base Plate Design Example
"Design of Structural Connections" p. 162

CONNECTION: BASE - Base Plate
Column: COL 530UB92.4 Gr.300
Base plate: 230x20x560 Gr.250 - Weld: 5 FW/480/SP

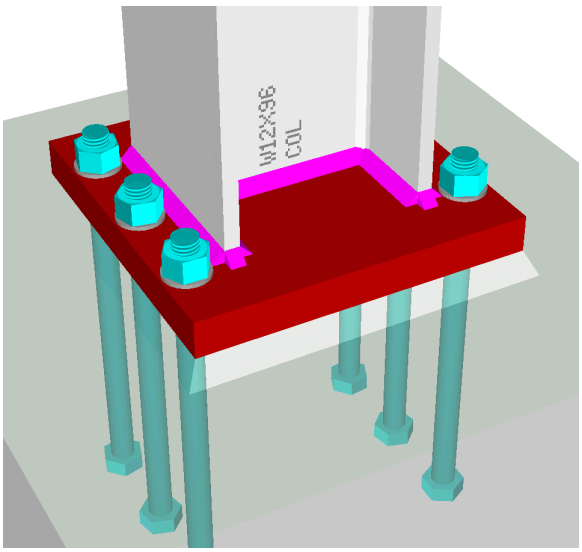


Foundation: 900 dia. x 600 deep - 40 thick grout pad
HD Bolts: 4-M20 4.6/S/N - 250 embedment

```
LIMCON V3.5                                                    31-OCT-06
                                                               21:51:59

 Connection: BASE
       Type: Base Plate
             1: Pinned base plate
    Country: Australia
      Units: Metric
Design code: AS 4100 (ASI 2006)

Column:  Mark=COL  Section=530UB92.4   Grade=300
     D =   533 mm    Root rad. =   14.0 mm    fyf =  300 MPa
     B =   209 mm         Area = 1.1800E+04   fyw =  320 MPa
    Tf =  15.6 mm           Sx = 2.3700E+06    fu =  440 MPa
    Tw =  10.2 mm

Base plate:
 560x230x20  Gr./fy/fu=250/250/410 MPa

Welds:
 5 FW fu=480 MPa/SP all around column.

Bolts:
 4-M20 4.6/S/N anchor bolts.
 No. bolt rows  = 2
 No. bolt cols. = 2
 Spacing of outer bolts, sg = 130 in XX direction.
 Spacing of outer bolts, sp = 400 in YY direction.
 Embedment length = 250, no hook.
 Shear capacity of bolts NOT considered.

No shear key.

Foundation:
```

```
 Foundation strength f'c =   25 MPa   Grout thickness = 40
 Circular, dia. = 900
 Min. bolt edge distance = 239.7
 Coeff. friction between base plate and foundation = 0.80

MINIMUM ACTION CHECK
Specified minimum design actions:
 Bending       30% of øMs (  639.9)  =  192.0 kN.m
 Shear                                 40.0 kN
 Tension        0% of øNs ( 3186.0)  =    0.0 kN
 Compression    0% of øNs ( 3186.0)  =    0.0 kN
 NOTE: Input design actions are not automatically increased if they are less than the
       specified minimum actions. Minimum actions may be set in any load case. This check
       warns if any design action is less than the specified minimum for all load cases.
 WARNING: Design bending moment is less than specified minimum.
 WARNING: Design shear force is less than specified minimum.

INPUT DESIGN ACTIONS
 Axial, N* . . . . . .   -90.0 kN  (comp.)
 Shear, Vx* . . . . . .    0.0 kN
 Shear, Vy* . . . . . .   25.0 kN
 Moment, Mx* . . . . . .   0.00 kN.m
 Moment, My* . . . . . .   0.00 kN.m
 NOTE: Bending moment is ignored.

DESIGN CAPACITY CHECKS...
                                          Capacity ratio --------+
                                          Design action --+      |
                                        +-- Design capacity |    |
                                        |                   |    |
NOTE: Capacity of section is not checked.

Using ASI 1994 model...

Compression analysis:
 Concrete confinement ratio  . . .    1.49
 Concrete foundation capacity  . . . . . .  2441.4  >  P'c   =   90.0  27.1  Pass
 Plate outstand cantilever capacity  . . . .  5878.5  >  P'c   =   90.0  65.3  Pass
 Fling plate thickness # . . . . . .    20.0  >  min.  =   26.0  0.77  Fail  Informative
 Modified Thornton plate capacity (Ref. 30)    832.5  >  P'c   =   90.0  9.25  Pass
 Column weld shear capacity (full contact) .  1481.9  >  V'r   =   25.0  59.3  Pass

Shear analysis:
 Friction...
  Coefficient of friction  . . . .    0.80
  Compression force  . . . . . .    90.0 kN
  Available base plate friction  . . . . . .    50.4 kN
  Design shear less friction (x) . . . . . .     0.0 kN
  Design shear less friction (y) . . . . . .     0.0 kN
 Total shear capacity (y)  . . . . . .    50.4  >  V'y   =   25.0  2.02  Pass

CRITICAL LIMIT STATE . . .  Total shear capacity (y)
UTILIZATION RATIO  . . . .     50%
CAPACITY RATIO, ø.Ru/S* .    2.016   Pass
```

Moment Base Plate

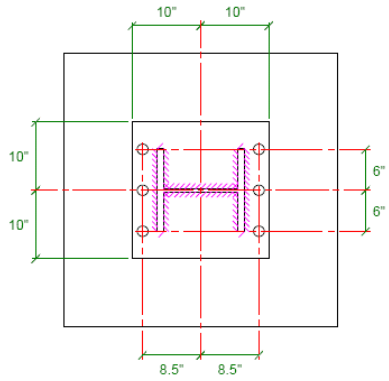


This is Example 4.7 from *Base Plate and Anchor Rod Design – 2nd Edition* – J.M. Fisher & L.A. Kloiber – AISC – 2006.

Limcon V3.5

Engineering Systems Development
Job: BASE SDG1 examples2 -- Connection: Ex.4.7

CONNECTION: Ex.4.7 - Base Plate
Column: COL W12X96 Gr.A992
Base plate: 20"x2.25"x20" Gr.A36 - Weld: 3/4" FW/70ksi

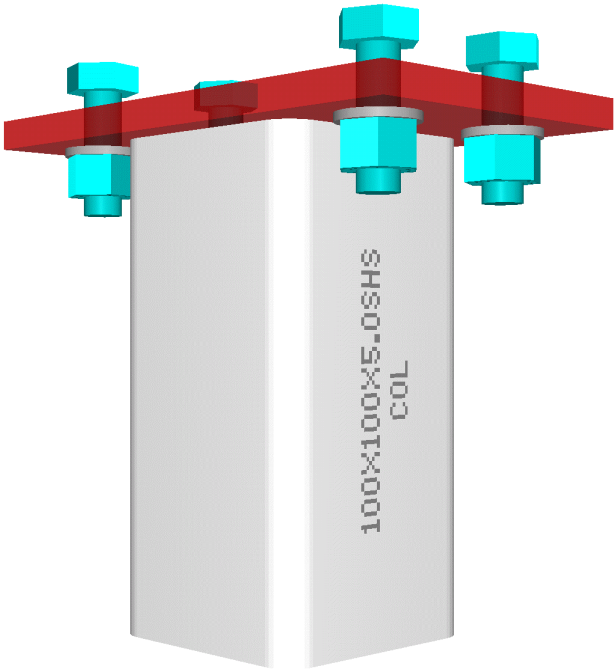


Foundation: 40" x 40" x 24" deep - 1-1/2" thick grout pad
HD Bolts: 6-1-1/2" A307/N - 18" embedment

```
Geometry Check:
*** WARNING -- Edge distance < minimum - check sp and di.
 0 error(s), 1 warning(s)

LIMCON V3.5                                                    31-OCT-06
                                                                22:20:29

 Connection: Ex.4.7
       Type: Base Plate
             2: Moment base plate
    Country: US
      Units: US customary
Design code: ANSI/AISC 360-05 (LRFD)

Column:  Mark=COL  Section=W12X96   Grade=A992
     D = 12.70 in.   Root rad. =   0.60 in.   fyf = 50.0 ksi
     B = 12.20 in.        Area = 2.8200E+01   fyw = 50.0 ksi
    Tf =  0.90 in.          Zx = 1.4700E+02    fu = 65.0 ksi
    Tw =  0.55 in.

Base plate:
 20"x20"x2.25"  Gr./Fy/Fu=A36/36.0/58 ksi

Welds:
 0.75" FW fu=70 ksi all around column.

Bolts:
 6-1-1/2" A307/N anchor bolts.
 No. bolt rows  = 2
 No. bolt cols. = 3
 Spacing of outer bolts, sg = 12" in XX direction.
 Spacing of outer bolts, sp = 17" in YY direction.
 Embedment length = 18", no hook.
 Shear capacity of bolts NOT considered.
```

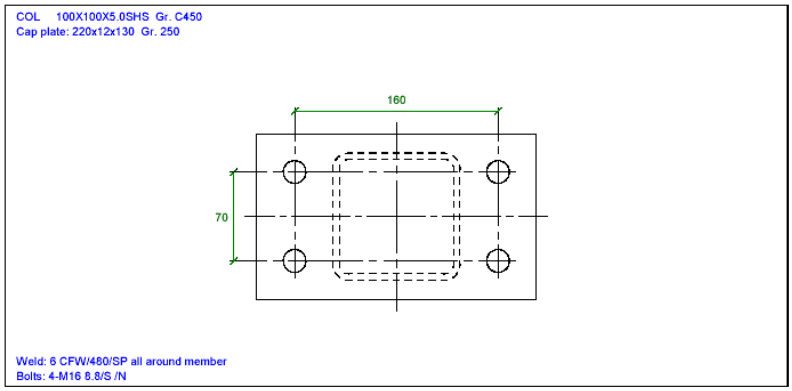
```
No shear key.

Foundation:
 Foundation strength f'c = 4.00 ksi   Grout thickness = 1.5"
 Rectangular, D = 40"      B = 40"
 Min. bolt edge distance = 11.5"
 Coeff. friction between base plate and foundation = 0.55

MINIMUM ACTION CHECK
Specified minimum design actions:
 Bending       30% of øMs ( 6615.0)  = 1984.5 kip-in
 Shear                                    9.0 kip
 Tension        0% of øNs ( 1269.0)  =    0.0 kip
 Compression    0% of øNs ( 1269.0)  =    0.0 kip
 NOTE: Input design actions are not automatically increased if they are less than the
       specified minimum actions. Minimum actions may be set in any load case. This check
       warns if any design action is less than the specified minimum for all load cases.
 WARNING: Design shear force is less than specified minimum.

INPUT DESIGN ACTIONS
 Axial, Nu . . . . . .  -376.0 kip (comp.)
 Shear, Vxu  . . . . . .     0.0 kip
 Shear, Vyu  . . . . . .     0.0 kip
 Moment, Mxu . . . . . .  3600.0 kip-in
 Moment, Myu . . . . . .     0.0 kip-in

DESIGN STRENGTH CHECKS...
                                              Strength ratio --------+
                                              Reqd. strength -+      |
                                            +-- Design strength |    |
                                            |                   |    |
NOTE: Capacity of section is not checked.

Using AISC 2006 model...

Compression + moment analysis:
 Concrete confinement ratio  . . .    2.00
 Bearing strength, fp(max) . . . .  4.42 ksi
 Foundation concentric compression strength   1768.0  >  Puc   =  376.0  4.70  Pass
 Strong Axis Bending...
  Eccentricity . . . . . .   9.57 in.
  Critical eccentricity  . . . . .   7.87 in.
  === Large moment - bolts in tension ===
  Bearing strength per unit length, qmax . .  88.400 kip/in
  Concrete bearing length, Y . . .   4.77 in.
  Concrete bearing force . . . . .   421.7 kip
  Total bolt tension, T  . . . . .    45.7 kip
  Single bolt tension strength . . . . . .    59.6  >  Tl    =   15.2  3.91  Pass
  Single bolt pull-out strength (unreinf.) .   321.7  >  Tl    =   15.2  21.1  Pass
  Base plate yield (bearing) strength  . . .   820.1  >  Mpb   =  695.8  1.18  Pass
  Bolt tension lever arm . . . . .   2.47 in.
  Base plate yield (tension) strength  . . .   820.1  >  Mpt   =  112.8  7.27  Pass
  Column weld strength . . . . . .  16.705  >  vures = 15.961  1.05  Pass

CRITICAL LIMIT STATE . . .   Column weld strength
UTILIZATION RATIO  . . . .     96%
STRENGTH RATIO . . . . . .   1.047   Pass
```

HSS Cap Plate Connection



This is the design example from p. 4-7 of *Design of Structural Steel Hollow Section Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Engineering Systems Development
Job: TCAP p.4-7 -- Connection: TCAP p.4-7
SSHS Cap Plate Design Example
"Design of Structural Steel Hollow Section Connections" p. 4-7

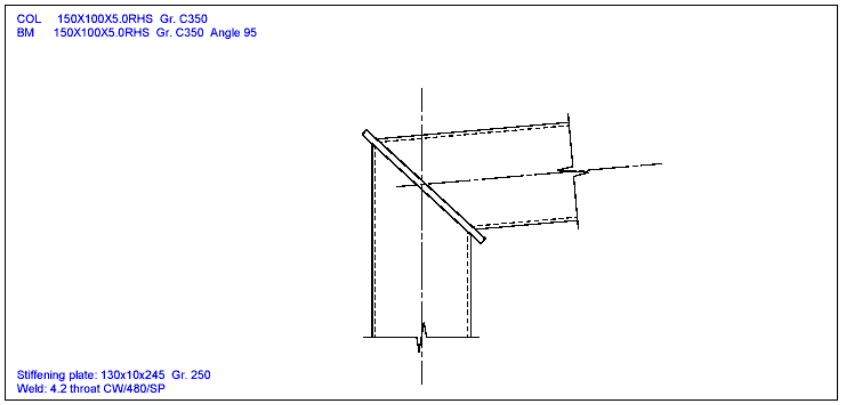



```
LIMCON V3.0                                                    13-DEC-02
                                                                10:47:01
 Connection: TCAP p.4-7
       Type: SSHS cap plate connection
Design code: AS4100/NZS3404

Member:  Mark=COL   Section=100X100X5.0SHS   Grade=C450
     D =  100.0          Area =  1.810E+03    fy = 400
     B =  100.0            Sx =  6.350E+04    fu = 500
     T =    5.0

Cap plate:
 130x220x12  Gr./fy/fu=250/260/410

Weld:
 6 CFW/480/SP all around.

Bolts:
 4-M16 8.8/S /N gauge 160 pitch 70

Design action   N* =   130.0t

ANALYSIS RESULT

Check validity ranges...
 Valid plate thickness range . . . . . .    12.0  >=    12.0         Pass
 Valid plate thickness range . . . . . .    12.0  <=    26.0         Pass

Component...
 Minimum plate thickness . . . . . .        12.0  >=    11.1         Pass
 Maximum plate thickness . . . . . .        12.0  <=    14.6         Pass
 Design capacity of plate  . . . . . .     280.1  >  N*t   =  130.0  Pass

Weld...
 Weld tension capacity . . . . . .         195.5  >  N*t   =  130.0  Pass

Bolts...
 Prying factor . . . . . .                 0.233
 Bolt tension capacity . . . . . .         338.2  >  N*t   =  130.0  Pass

Critical limit state:  Weld tension capacity
            ø.Ru/S*:    1.504   Pass
```

HSS Mitred Knee

This is the design example from p. 10-9 of *Design of Structural Steel Hollow Section Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Engineering Systems Development
Job: KNEE p.10-9 -- Connection: KNEE p.10-9
Mitred Knee Design Example
"Design of Structural Steel Hollow Section Connections" p. 10-9




```
LIMCON V3.0                                                    12-DEC-02
                                                                19:54:26
 Connection: KNEE p.10-9
       Type: SSHS mitred knee connection
Design code: AS4100/NZS3404

Column:  Mark=COL   Section=150X100X5.0RHS   Grade=C350
     D =  150.0          Area =  2.310E+03    fy = 350
     B =  100.0            Sx =  1.150E+05    fu = 430
     T =    5.0

Rafter:  Mark=BM   Section=150X100X5.0RHS   Grade=C350
     D =  150.0          Area =  2.310E+03    fy = 350
     B =  100.0            Sx =  1.150E+05    fu = 430
     T =    5.0
 Angle between column and rafter = 95.00

Stiffening plate:
 245x130x10  Gr./fy/fu=250/260/410

Weld:
 4.2 throat CW/480/SP around end of member.

Input design actions:
                Column    Rafter
 Moment          25.0      25.0
 Shear           48.0      45.0
 Axial          -32.0c    -20.0c

ANALYSIS RESULT

Minimum design actions - column:
 Bending       50% of øMs(   36.2)  =    18.1 kN.m
 Shear         15% of øVv(  256.1)  =    38.4 kN - governs
  or                                    40.0 kN

Minimum design actions - rafter:
 Bending       50% of øMs(   36.2)  =    18.1 kN.m
 Shear         15% of øVv(  256.1)  =    38.4 kN - governs
```

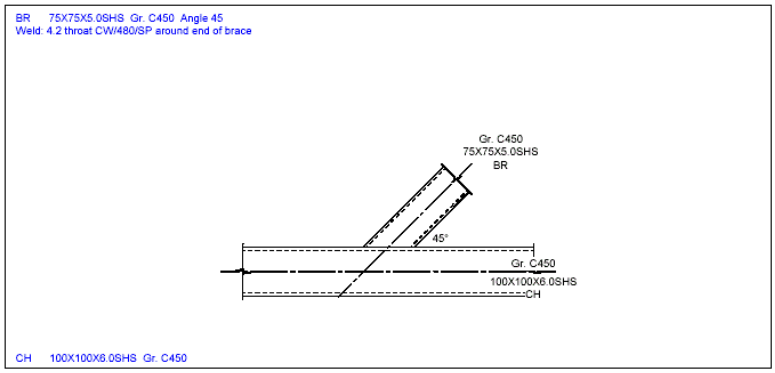
Engineering Systems Development
Job: KNEE p.10-9 -- Connection: KNEE p.10-9
Mitred Knee Design Example
"Design of Structural Steel Hollow Section Connections" p. 10-9

```
   or                                        40.0 kN

 Final design actions:
                  Column     Rafter
  Moment           25.0       25.0
  Shear            48.0       45.0
  Axial           -32.0c     -20.0c

 Check validity ranges...

  Section widths  . . . . . .  100.0  =    100.0          Pass
  Angle, theta  . . . . . .     95.0  >=    90.0          Pass
                                95.0  <    180.0          Pass

  COLUMN:
  Thickness, t1 . . . . . .      5.0  >      2.0          Pass
                                 5.0  <=    25.0          Pass
  d1/b1 . . . . . .             1.50  >=    0.33          Pass
                                1.50  <=    3.50          Pass
  Section slenderness plasticity limit  . . .  30.0
  Section slenderness yield limit . . . . . .  40.0
  Section slenderness . . . . . .  21.3
   Compactness = C - Pass
  b1  . . . . . .  100.0  <=   400.0          Pass
  d1  . . . . . .  150.0  <=   400.0          Pass
  tp  . . . . . .   10.0  >=     7.5          Pass
                    10.0  >=    10.0          Pass

  RAFTER:
  Thickness, t2 . . . . . .      5.0  >      2.0          Pass
                                 5.0  <=    25.0          Pass
  d2/b2 . . . . . .             1.50  >=    0.33          Pass
                                1.50  <=    3.50          Pass
  Section slenderness plasticity limit  . . .  30.0
  Section slenderness yield limit . . . . . .  40.0
  Section slenderness . . . . . .  21.3
   Compactness = C - Pass
  b2  . . . . . .  100.0  <=   400.0          Pass
  d2  . . . . . .  150.0  <=   400.0          Pass
  tp  . . . . . .   10.0  >=     7.5          Pass
                    10.0  >=    10.0          Pass

 Combined moment and axial load...
  COLUMN:
  Sum of capacity ratios  . . . . . .  0.734  <=   1.000          Pass
  RAFTER:
  Sum of capacity ratios  . . . . . .  0.718  <=   1.000          Pass

 Shear...
  COLUMN:
  0.5 x Shear capacity  . . . . . .  128.0  >  V*1   =   48.0  Pass
  RAFTER:
  0.5 x Shear capacity  . . . . . .  128.0  >  V*2   =   45.0  Pass

 Weld...
  COLUMN:
  Column weld capacity per unit length  . . .  0.977  >  v*res =  0.760  Pass
  RAFTER:
  Rafter weld capacity per unit length  . . .  0.977  >  v*res =  0.808  Pass

 Critical limit state:  Rafter weld capacity per unit length
              ø.Ru/S*:    1.209   Pass
```

HSS Y or T Connection

This is the design example from p. 11-19 of *Design of Structural Steel Hollow Section Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Engineering Systems Development
Job: TYT p.11-19 -- Connection: TYT p.11-19
Y or T Connection Design Example
"Design of Structural Steel Hollow Section Connections" p. 11-19

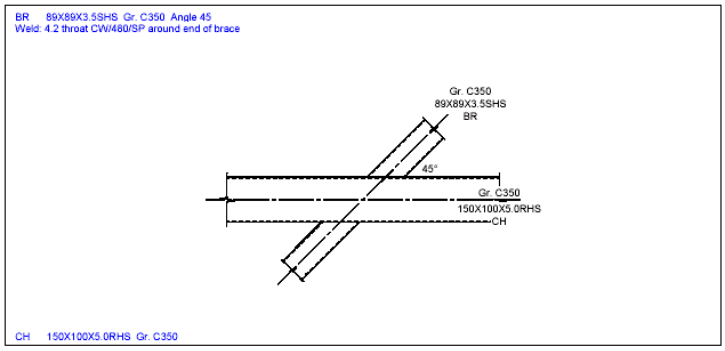



```
LIMCON V3.0                                                    19-JAN-03
                                                               10:33:05
 Connection: TYT p.11-19
       Type: SSHS Y/T connection
Design code: AS 4100

Chord:  Section=100X100X6.0SHS   Grade=C450
     D =  100.0          Area =  2.130E+03    fy = 400
     B =  100.0            Sx =  7.350E+04    fu = 500
     T =    6.0

Brace:  Mark=BR   Section=75X75X5.0SHS   Grade=C450
     D =   75.0          Area =  1.310E+03    fy = 400
     B =   75.0            Sx =  3.360E+04    fu = 500
     T =    5.0
 Angle between brace and chord = 45.00

Weld:
 4.2 throat CW/480/SP around end of brace.

Design actions:
 Axial force              N*    =  -250.0c
 Axial preload in chord   N*op =   123.0
 Bending moment in chord  M*o  =     4.0

ANALYSIS RESULT - Compression

 Minimum design action . . . . . .   141.5

 Design axial load in chord (derived)  . . .     300

 Configuration: SHS chord...

 (a) b1/b0 for SHS brace . . . . . .    0.75  >=    0.25          Pass
                                        0.75  <=    0.85          Pass
 (b)(ii) b/t for SHS brace . . . . . .  15.0  <=    28.0          Pass
                                        15.0  <=    35.0          Pass
 (c) b/t for SHS chord . . . . . .      16.7  >=    10.0          Pass
                                        16.7  <=    35.0          Pass

 Na = chord face yielding capacity . . . . .   343.9  >  N*     =  250.0  Pass
 Length of weld  . . . . . .              .     287
 Nb = weld capacity for specified throat . .   280.5  >  N*     =  250.0  Pass

Critical limit state:  Nb = weld capacity for specified throat
            ø.Ru/S*:    1.122   Pass
```

HSS X Connection

This is the design example from p. 12-19 of *Design of Structural Steel Hollow Section Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Engineering Systems Development
Job: TX p.12-19 -- Connection: TX p.12-19
SSHS X Connection Design Example
"Design of Structural Steel Hollow Section Connections" p. 12-19



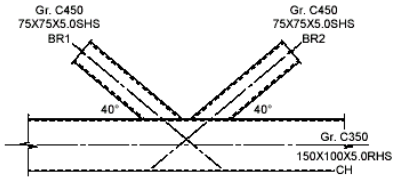

```
LIMCON V3.0                                                    12-DEC-02
                                                               22:34:13
 Connection: TX p.12-19
       Type: SSHS X connection
Design code: AS4100/NZS3404

Chord:  Section=150X100X5.0RHS   Grade=C350
     D =  150.0          Area =  2.310E+03    fy = 350
     B =  100.0            Sx =  1.150E+05    fu = 430
     T =    5.0

Brace:  Mark=BR   Section=89X89X3.5SHS   Grade=C350
     D =   89.0          Area =  1.150E+03    fy = 350
     B =   89.0            Sx =  3.650E+04    fu = 430
     T =    3.5
 Angle between brace and chord = 45.00

Weld:
 4.2 throat CW/480/SP around end of brace.

Design action   N* =   200.0t

ANALYSIS RESULT - Tension

 Minimum design action . . . . . .   108.7

 Design axial load in chord (derived)  . . .     141

 Configuration: RHS chord...

 (a) b1/b0 for RHS/SHS brace . . . . . .    0.89  >=    0.25          Pass
 (a) h1/b0 for RHS/SHS brace . . . . . .    0.89  >=    0.25          Pass
 (c) h/b for RHS/SHS brace . . . . . .      1.00  >=    0.50          Pass
                                            1.00  <=    2.00          Pass
 (d) b/t for RHS/SHS chord . . . . . .      20.0  <=    35.0          Pass
 (d) h/t for RHS/SHS chord . . . . . .      30.0  <=    35.0          Pass
 (b)(i) b/t for RHS/SHS brace  . . . . .    25.4  <=    35.0          Pass
 (b)(i) h/t for RHS/SHS brace  . . . . .    25.4  <=    35.0          Pass

 Effective width . . . . . .      63.6
 Nc = brace effective width capacity . . .   356.7  >  N*    =  200.0  Pass
 Nd = punching shear capacity  . . . . . .   506.0  >  N*    =  200.0  Pass
 Nb = chord side wall / face capacity  . .   516.2  >  N*    =  200.0  Pass
 Ng = chord side wall shear failure  . . .   445.5  >  N*    =  200.0  Pass
 Length of weld  . . . . . .      341
 Nh = weld capacity for specified throat . .  332.9  >  N*    =  200.0  Pass

Critical limit state:  Nh = weld capacity for specified throat
             ø.Ru/S*:    1.664   Pass
```

HSS T or K Gap Connection

This is the design example from p. 13-21 of *Design of Structural Steel Hollow Section Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Engineering Systems Development
Job: TKNG p.13-21 -- Connection: TKNG p.13-21
SSHS K or N Gap Connection Design Example
"Design of Structural Steel Hollow Section Connections" p. 13-21

BR1 75X75X5.0SHS Gr. C450 Angle 40
BR2 75X75X5.0SHS Gr. C450 Angle 40
Weld: 4.2 throat CW/480/SP around end of brace



Gap 20
Chord: CH 150X100X5.0RHS Gr. C350

```
LIMCON V3.0                                                    12-DEC-02
                                                               23:24:14
 Connection: TKNG p.13-21
       Type: SSHS K/N gap connection
Design code: AS4100/NZS3404

Chord:  Section=150X100X5.0RHS   Grade=C350
     D =  150.0          Area =  2.310E+03    fy = 350
     B =  100.0            Sx =  1.150E+05    fu = 430
     T =    5.0

Brace 1:  Mark=BR1   Section=75X75X5.0SHS   Grade=C450
     D =   75.0          Area =  1.310E+03    fy = 400
     B =   75.0            Sx =  3.360E+04    fu = 500
     T =    5.0
 Angle between brace and chord = 40.00

Brace 2:  Mark=BR2   Section=75X75X5.0SHS   Grade=C450
     D =   75.0          Area =  1.310E+03    fy = 400
     B =   75.0            Sx =  3.360E+04    fu = 500
     T =    5.0
 Angle between brace and chord = 40.00

Gap =   20 mm

Weld:
 4.2 throat CW/480/SP around end of brace.

Design actions:
 Axial force - brace 1    N*1  =  -250.0c
 Axial force - brace 2    N*2  =   200.0t
 Axial preload in chord   N*op =     0.0
 Bending moment in chord  M*o  =    10.7
 Axial force in chord     N*o  =   300.0
 Shear force in chord     V*o  =    16.0

ANALYSIS RESULT

 Minimum design action - brace 1 . . . . . .   141.5
```

Engineering Systems Development
Job: TKNG p.13-21 -- Connection: TKNG p.13-21
SSHS K or N Gap Connection Design Example
"Design of Structural Steel Hollow Section Connections" p. 13-21

Minimum design action - brace 2	141.5				
Configuration: RHS chord...					
A = h1/(2 x sinθ1)	58.34				
B = h2/(2 x sinθ2)	58.34				
C = (sinθ1 x sinθ2)/sin(θ1 + θ2)	0.42				
D = h0/2	75.00				
Eccentricity, e	-17.66				
(a) b1/b0 for RHS/SHS brace 1	0.75	>=	0.30		Pass
(a) h1/b0 for RHS/SHS brace 1	0.75	>=	0.30		Pass
(a) b2/b0 for RHS/SHS brace 2	0.75	>=	0.30		Pass
(a) h2/b0 for RHS/SHS brace 2	0.75	>=	0.30		Pass
(b) ß for RHS/SHS braces	0.75	>=	0.35		Pass
(c)(ii) b1/t1 for RHS/SHS brace 1	15.0	<=	28.0		Pass
	15.0	<=	35.0		Pass
(c)(i) b2/t2 for RHS/SHS brace 2	15.0	<=	35.0		Pass
(e) b0/t0 for RHS chord	20.0	<=	35.0		Pass
(e) h0/t0 for RHS chord	30.0	<=	35.0		Pass
(f)(i) Gap: g/b0	0.20	>=	0.12		Pass
	0.20	<=	0.38		Pass
(f)(ii) Gap less than (t1+t2)	20.0	>=	10.0		Pass
(g) e/h0 for RHS chord	-0.12	>=	-0.55		Pass
	-0.12	<=	0.25		Pass
Na1 = RHS chord face plastification cap. .	267.0	>	N*	= 250.0	Pass
Na2 = RHS chord face plastification cap. .	267.0	>	N*	= 200.0	Pass
Nb1 = RHS chord shear capacity	524.6	>	N*	= 250.0	Pass
Nb2 = RHS chord shear capacity	524.6	>	N*	= 200.0	Pass
øNog = axial capacity of chord	807.9	>	N*	= 300.0	Pass
Effective width	32.8				
Nc1 = brace effective width capacity . . .	475.6	>	N*	= 250.0	Pass
Effective width	32.8				
Nc2 = brace effective width capacity . . .	475.6	>	N*	= 200.0	Pass
Nd1 = RHS chord punching shear capacity . .	565.0	>	N*	= 250.0	Pass
Nd2 = RHS chord punching shear capacity . .	565.0	>	N*	= 200.0	Pass
Length of weld - brace 1	308				
Ne1 = weld capacity for specified throat .	301.2	>	N*	= 250.0	Pass
Length of weld - brace 2	308				
Ne2 = weld capacity for specified throat .	301.2	>	N*	= 200.0	Pass

Critical limit state: Na1 = RHS chord face plastification cap.
ø.Ru/S*: 1.068 Pass

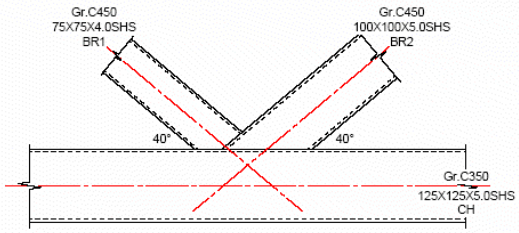
HSS T or K Overlap Connection

This is the design example from p. 14-15 of *Design of Structural Steel Hollow Section Connections*. The printed output on the following pages is obtained by clicking the Print button in the connection dialog box.

Limcon V3.5

Engineering Systems Development
Job: TKNO p.14-15 -- Connection: TKNOp.14-15
SSHS T or K Overlap Connection Design Example
"Design of Structural Steel Hollow Section Connections" p. 14-15

CONNECTION: TKNOp.14-15 - HSS K/N Overlap Connection
BR1 75X75X4.0SHS Gr.C450 Angle 40
BR2 100X100X5.0SHS Gr.C450 Angle 40
Weld: 4.2 throat/480/SP around end of brace



Overlap 70 Eccentricity -34.8
Chord: CH 125X125X5.0SHS Gr.C350

```
Geometry Check:
*** WARNING -- Weld throat exceeds HSS thickness.
 0 error(s), 1 warning(s)

LIMCON V3.5                                                    17-MAY-08
                                                                21:22:46

 Connection: TKNOp.14-15
       Type: HSS K/N Overlap Connection
    Country: Australia
      Units: Metric
Design code: AS 4100

Chord:  Section=125X125X5.0SHS   Grade=C350
     D =    125 mm        Area =    2310       fy =  350 MPa
     B =    125 mm          Sx = 1.0300E+05    fu =  430 MPa
     T =      5 mm
 Section bending capacity  . . . .    32.4 kN.m
 Section shear capacity  . . . . .   118.1 kN
 Section axial capacity  . . . . .   727.7 kN

Brace 1:  Mark=BR1  Section=75X75X4.0SHS   Grade=C450
     D =     75 mm        Area =    1080       fy =  400 MPa
     B =     75 mm          Sx = 2.8200E+04    fu =  500 MPa
     T =      4 mm
 Section bending capacity  . . . .    10.2 kN.m
 Section shear capacity  . . . . .    72.9 kN
 Section axial capacity  . . . . .   410.4 kN
 Angle between brace and chord = 40.00 deg.

Brace 2:  Mark=BR2  Section=100X100X5.0SHS   Grade=C450
     D =    100 mm        Area =    1810       fy =  400 MPa
     B =    100 mm          Sx = 6.3500E+04    fu =  500 MPa
     T =      5 mm
 Section bending capacity  . . . .    22.9 kN.m
 Section shear capacity  . . . . .   121.5 kN
 Section axial capacity  . . . . .   688.1 kN
 Angle between brace and chord = 40.00 deg.

Overlap  . . . . . .      70 mm
 Brace 1 overlaps brace 2.

Weld:
 4 throat fu=480 MPa/SP around end of brace.

 MINIMUM ACTIONS NOT CHECKED

 INPUT DESIGN ACTIONS
  Axial force - brace 1,       N*1  =  200.0 kN  (tens.)
  Axial force - brace 2,       N*2  = -300.0 kN  (comp.)
  Axial preload in chord,      N*op =    0.0 kN
```

```
 Max. axial force in chord,   N*o  =    0.0 kN
 Bending moment in chord,     M*o  =   0.00 kN.m

Using ASI 1996 model...

SECTION CHECKS...
 Chord section yield capacity  . . . . . .   727.7  ≥  N*o   =    0.0    0%  Pass
 Brace 1 section yield capacity  . . . . .   388.8  ≥  N*1   =  200.0   51%  Pass
 Brace 2 section yield capacity  . . . . .   651.6  ≥  N*2   =  300.0   46%  Pass

BRANCH CONFIGURATION CHECKS...
 Chord normal force 1  . . . . . .   128.6 kN
 Chord normal force 2  . . . . . .  -192.8 kN
 Out of balance normal force % . .     50%
 Chord axial force 1 . . . . . .    153.2 kN
 Chord axial force 2 . . . . . .   -229.8 kN
 Total chord axial force . . . . .   383.0 kN
 Brace 1 strength  . . . . . .     1.600 kN/mm
 Brace 2 strength  . . . . . .     2.000 kN/mm
 NOTE: Full circumference of brace 2 must be welded to chord.

GEOMETRY CHECKS...
 Configuration: RHS/SHS chord...
  A = h1/(2 x sinθ1) . . . . . .      58 mm
  B = h2/(2 x sinθ2) . . . . . .      78 mm
  C = (sinθ1 x sinθ2)/sin(θ1 + θ2)   0.420
  D = h0/2 . . . . . .      63 mm
  Eccentricity, e  . . . . . .     -35 mm
  Overlap %  . . . . . .   59.99

 (a) b1/b0 for RHS/SHS brace 1 . .      0.60          ≥    0.25              Pass
 (a) h1/b0 for RHS/SHS brace 1 . .      0.60          ≥    0.25              Pass
 (a) b2/b0 for RHS/SHS brace 2 . .      0.80          ≥    0.25              Pass
 (a) h2/b0 for RHS/SHS brace 2 . .      0.80          ≥    0.25              Pass
 (b)(i) b1/t1 for RHS/SHS brace 1      18.8           ≤    35.0              Pass
 (b)(ii) b2/t2 for RHS/SHS brace 2     20.0           ≤    24.6              Pass
                                       20.0           ≤    35.0              Pass
 (d) b0/t0 for RHS/SHS chord . . .     25.0           ≤    40.0              Pass
 (d) h0/t0 for RHS/SHS chord . . .     25.0           ≤    40.0              Pass
 (e) Overlap % . . . . . .     60.0           ≥    25.0              Pass
                                       60.0           ≤   100.0              Pass
 (f) t1/t2 for RHS/SHS/CHS braces      0.80           ≤    1.00              Pass
 (g) b1/b2 for RHS/SHS braces  . .     0.75           ≥    0.75              Pass
 (h) e/h0 for RHS/SHS chord  . . .    -0.28           ≥   -0.55              Pass
                                      -0.28           ≤    0.25              Pass

DESIGN CAPACITY CHECKS...
                                                  Utilization ratio ──────┐
                                                  Design action ──┐       │
                                              ┌── Design capacity │       │
                                              │                   │       │
 Nb1 = overlapping brace eff. width capacity   341.9  ≥  N*    =  200.0   58%  Pass
 Nb2 = overlapped brace eff. width capacity    573.0  ≥  N*    =  300.0   52%  Pass

┌──────────────────────────────────────────────────────────────────────────┐
│  NOTE:   Weld checks are based on some simplifying assumptions.          │
│          Please see Limcon User Manual or on-line help for details.      │
│          See Ref. 12 p.14-12.                                            │
└──────────────────────────────────────────────────────────────────────────┘
 Brace 1 weld:
  Weld length for zero overlap . .     308 mm
  Weld length for 100% overlap . .     152 mm
  Interpolated weld length . . . .     215 mm
  Weld capacity for specified throat . . . .   209.8  ≥  N*    =  200.0   95%  Pass
 Brace 2 weld:
  Weld force for zero overlap  . .   300.0 kN
  Weld force for 100% overlap  . .   388.4 kN
  Interpolated weld force  . . . .   353.0 kN
  Effective weld length  . . . . .     411 mm
  Weld capacity for specified throat . . . .   401.6  ≥           353.0   88%  Pass

CRITICAL LIMIT STATE . . .   Weld capacity for specified throat
UTILIZATION RATIO  . . . .     95%
CAPACITY RATIO, ø.Ru/S* .    1.049   Pass
```

A:Appendix

User-Defined Steel Grades

The grade of steel is selected for sections and plates from the drop-down list of a **Grade** combo box, see “Steel Grades” on p. 39. The grades available in the list depend on the Country setting in the General Configuration dialog box but all grades may be included by checking International. If you wish to include a grade that is not in the list you may define up to 10 user grades. These will be shown at the end of the list of grades and are distinguished by an asterisk in front of the grade name.

```
! File: USER_GRADES.txt
! Folder: \Limcon\Lib
! ! character in col. 1 denotes comment.
! Max. no. user grade categories = 20.
! Each line must contain at least these values...
!  1 = Grade name - starting in col. 1, 5 char. max., no asterisk.
!  2 = Us, N/mm2                                  430 for S275
!  3 = T1, mm thickness <=                         16 for S275
!  4 = py1, N/mm2                                 275 for S275
! Two values for each additional thickness...
!  5 = T2, mm thickness <=                         40 for S275
!  6 = py2, N/mm2                                 265 for S275
!  7 = T3, mm thickness <=                         63 for S275
!  8 = py3, N/mm2                                 255 for S275
!  9 = T4, mm thickness <=                         80 for S275
! 10 = py4, N/mm2                                 245 for S275
! 11 = T5, mm thickness <=                        100 for S275
! 12 = py5, N/mm2                                 235 for S275
! 13 = T6, mm thickness <=                        150 for S275
! 14 = py6, N/mm2                                 225 for S275
!
User1 401 10 301 20 291 30 281 40 271 50 261 60 251
User2 402 10 302 20 292 30 282 40 272 50 262
```

FORMAT FOR GRADES.TXT FILE

User-defined grades are specified in a file called User_grades.txt, which must be in the \Limcon\Lib folder. The format rules for the file are shown in the sample file, above.

User-Defined Bolt Categories

The bolt category is selected from the drop-down list of a **Categ.** combo box, see “Bolts” on p. 41. The bolting categories in the list depend on the Country setting in the General Configuration dialog box but all categories may be included by checking International. If you wish to include a bolting category that is not in the list you may define up to 10 user categories. These will be shown at the end of the list of bolt categories and are distinguished by an asterisk in front of the category name.

```
! File: USER_BOLTS.txt
! Folder: \Limcon\Lib
! ! character in col. 1 denotes comment.
! Max. no. user bolt categories = 10.
! Each line must contain these variables...
!  1 = Category name - starting in col. 1, 5 char. max., no asterisk.
!  2   0=bearing 1=friction
!  3   0=untensioned 1=tensioned
!  4 = ultimate tensile stress, N/mm2           830 for 8.8
!  5 = yield stress, N/mm2                      662 for 8.8
!  6 = pt, N/mm2 - tension strength <=M24       560 for 8.8
!  7 = pt, N/mm2 - tension strength >=M27       560 for 8.8
!  8 = ps, N/mm2 - shear strength <=M24         375 for 8.8
!  9 = ps, N/mm2 - shear strength >=M27         375 for 8.8
! 10 = pbb, N/mm2 - bolt bearing <=M24         1000 for 8.8
! 11 = pbb, N/mm2 - bolt bearing >=M27         1000 for 8.8
!
User1 0 0 830 664 560 560 375 375 1000 1000
User2 1 1 830 664 560 560 375 375 1000 1000
```

FORMAT FOR BOLTS.TXT FILE

User-defined bolt categories are specified in a file called User_bolts.txt, which must be in the \Limcon\Lib folder. The format rules for the file are shown in the sample file, above.

This facility has been used to define bolts with particular properties, e.g. anchor bolts with strength reduced by corrosion.

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